METAL PROGRESS

CTOBER 1933

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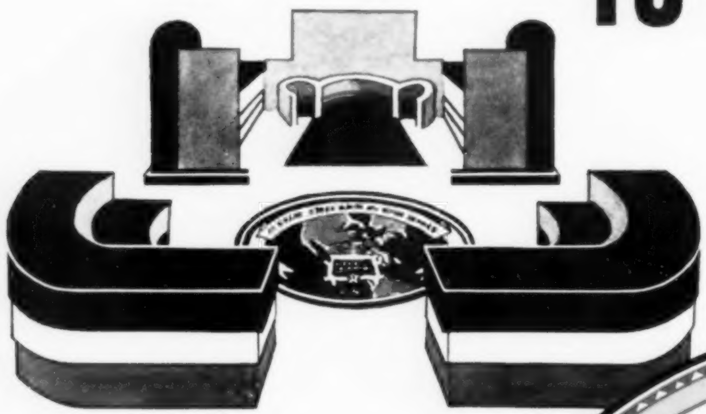

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METAL PROGRESS

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Vol. 24, No. 4, October, 1933

 Issued monthly, subscription $5 a year. Entered as second-class matter, Feb. 7, 1921, at the post office at Cleveland, O., under the Act of March 3, 1870 . . . .

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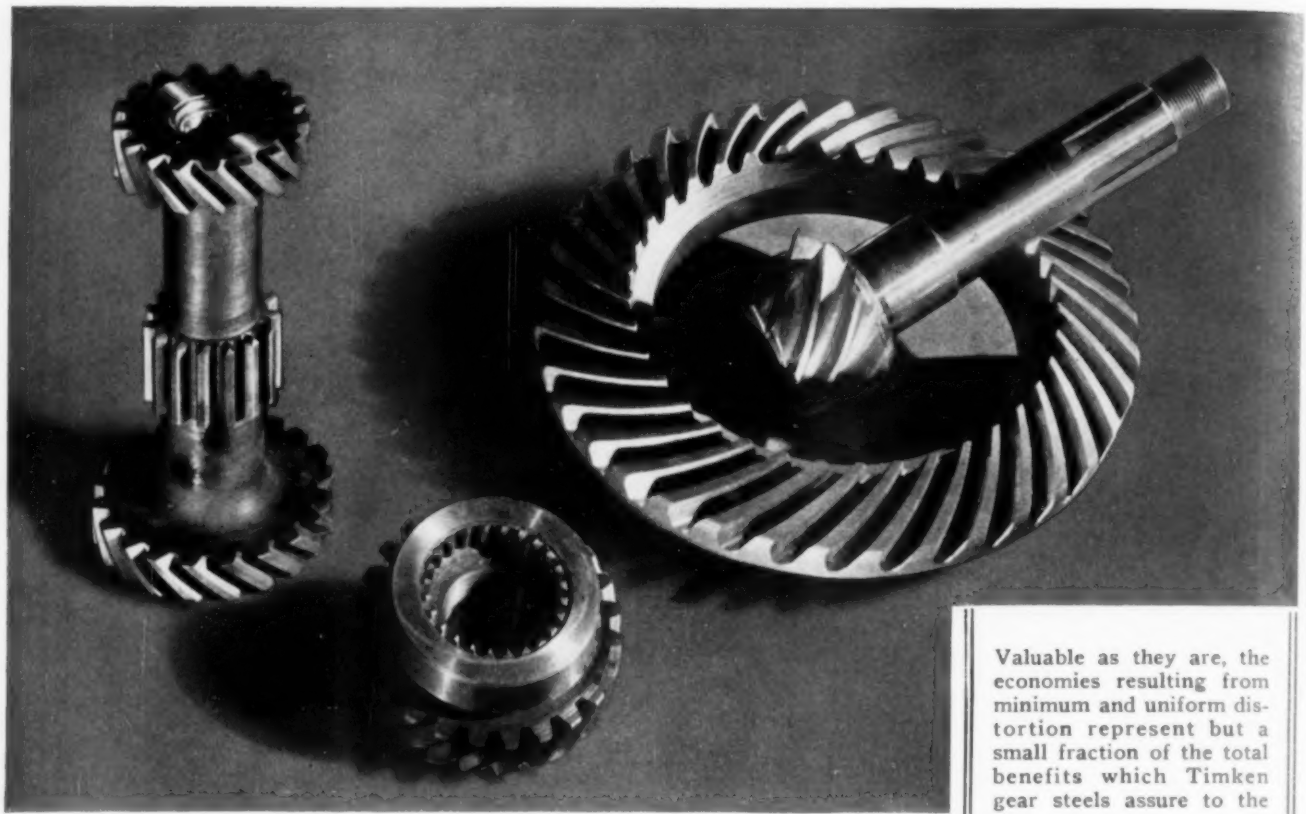
Ernest E. Thum, Editor.



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By Francis F. Lucas, Bell Telephone Laboratories

A PRECISION, HIGH POWER METALLOGRAPHIC APPARATUS

ONE might assume that to extend the range of the microscope, radical changes in optics and principles would be required. This is probably more nearly true today than it was ten years ago, for recent development of high power metallography depended upon the fact that the available optics were not being used efficiently.

Since the development of apochromatic objectives (1886), science has had available an optical system capable of resolving about 140,000 lines per inch. That is to say, if a ruling having 140,000 uniformly engraved and spaced lines were photographed under favorable conditions, the lines should be resolved as individuals and each line clearly separated from its neighbors. To resolve a greater number of lines with equal brilliancy, either the numerical aperture of the objective must be increased or the wave-length of the light used to photograph the specimen must be decreased.

All of these factors were well known and recognized years ago. Likewise it was known that the optical and associated parts of a high power photomicrographic apparatus must be solidly assembled to be free from vibratory disturbances, or at least it must vibrate as a unit. Exact optical alignment of the parts was also recognized as necessary. As the magnification is increased the difficulties mount; longer exposures are required for higher magnifications unless more sensitive plates can be procured.

Summarizing the desirable characteristics in precision equipment for photographing at magnifications from 4000 to 6000 diameters, we require great mechanical stability, freedom from creep, absolute freedom from outside disturbances, the means to illuminate the specimen with light of any selected wave-lengths within the visible spectrum, and the highest order of achievement in optical equipment. This is a large order!

In 1927 Bell Telephone Laboratories undertook to design a microscope as nearly perfect mechanically as possible, with the most efficient optical systems yet devised. After four years of work by Zeiss Co., Jena, Germany, this equipment was delivered and installed in a laboratory specially prepared to receive it. Enough work has been done in the last two years to appraise its excellences and its limitations. (The complete paper describes the details of the apparatus and its manipulation.)

The color of the light used to photograph a given metallurgical

Extracts from a Paper for A.S.S.T. Convention

specimen may have a very important bearing on the detail revealed. Let it be said, however, that a shift from red to blue light with shorter wave-length does not necessarily mean that a substantial increase in resolution of a given specimen will be apparent at once. Selective absorption also plays a part because contrast is also developed. With very careful work and with attention to all related details it will be found that a given detail with blue light will appear somewhat sharper than with red or green light. If a constituent absorbs blue light and the background reflects it, then short wave-length promotes resolution. However, if the constituent absorbs red light and both the background and the constituent reflect blue light, better photographic results may actually be achieved by using red light in preference to blue.

"Lines-per-inch" is not a very fortunate yardstick for evaluating resolution because few metallographic specimens exhibit a uniform arrangement and spacing of detail characteristic of a ruled grating. It seems extremely doubtful if a ruling was ever made so clearly defined and so perfectly revealed as the detail of a very finely prepared and etched metallographic specimen. Perhaps the nearest approach to perfection is in the age hardening phenomenon in which a hard constituent is precipitated from the matrix so fine in particle size that we see millions of particles only as a cloud. Under suitable treatment they may be induced to grow so that they may be recognized as single particles. When dealing with such very fine particles the utmost in resolving power, in skill, and in ingenuity is required. The frontispiece is an illustration of such a metallographic "grating."

If one assumes, because the formula calls for a resolution of 110,000 lines per inch with a dominant wave-length of 6500 Ångstrom units (red light) and a resolution of 160,000 lines with a dominant wave-length of 4500 Å (blue light), that a mere shift in filters from red to blue will bring 50,000 more lines into vision, he is doomed to disillusionment. While it is highly desirable to have complete control over the wave-length of light to be used, the photographing of very minute details at high powers also involves preparation of the specimen and many other contributing factors.

When a filter is spoken of as transmitting a certain dominant wave-length it is meant, of course, that the light which it transmits is maximum at the dominant wave-length. The filters ordinarily used transmit "zones" in the spectrum — for example, blue light from 4000 Å to 5000 Å, but its dominant wave-length may be 4500 Å. So in photographing with filters, one does not use a *single* wave-length of light or a limited group of wave-lengths, but a broad band of wave-lengths the intensities of which may gradually increase from zero to a maximum and then decrease again to zero.

Keeping in mind that the very best apochromatic objectives are only an approximation at bringing all of the different wave-lengths to a common focus, it becomes apparent that in a precision metallographic apparatus means should be available for working with light of a given wave-length and excluding all others. A further advance in this direction would be to have "monochromats" rather than apochromats — that is, objectives with very fine spherical correction for a given wave-length in the visible spectrum. Chromatic errors do not occur for a single wave-length.

In this particular apparatus, a step has been taken in this direction by making use of the mono-brom-naphthalene objective of N.A. 1.60 which has now been corrected for the blue region of the visible spectrum. This probably represents the highest achievement yet attained, and permits one to employ the shorter wave-lengths with these very high aperture objectives.

When the intensity of the light is decreased by using monochromatic light (or a very narrow group of lines), a much longer exposure will be required for the same plates. Heretofore the exposure was limited to about 1.5 min. because the equipment lacked mechanical stability. Hence much thought was given to this point so that longer exposures could be made.

Fortunately, also, the Eastman Kodak Co. has developed a metallographic plate which is much more sensitive to the blue and green regions of the spectrum. These plates have greatly simplified the problem and are ideal in quality and speed. As a result, the longest exposures thus far made have been of 30 min. Crisp, brilliant images of proper density have resulted at magnifications of 4000 diameters, as

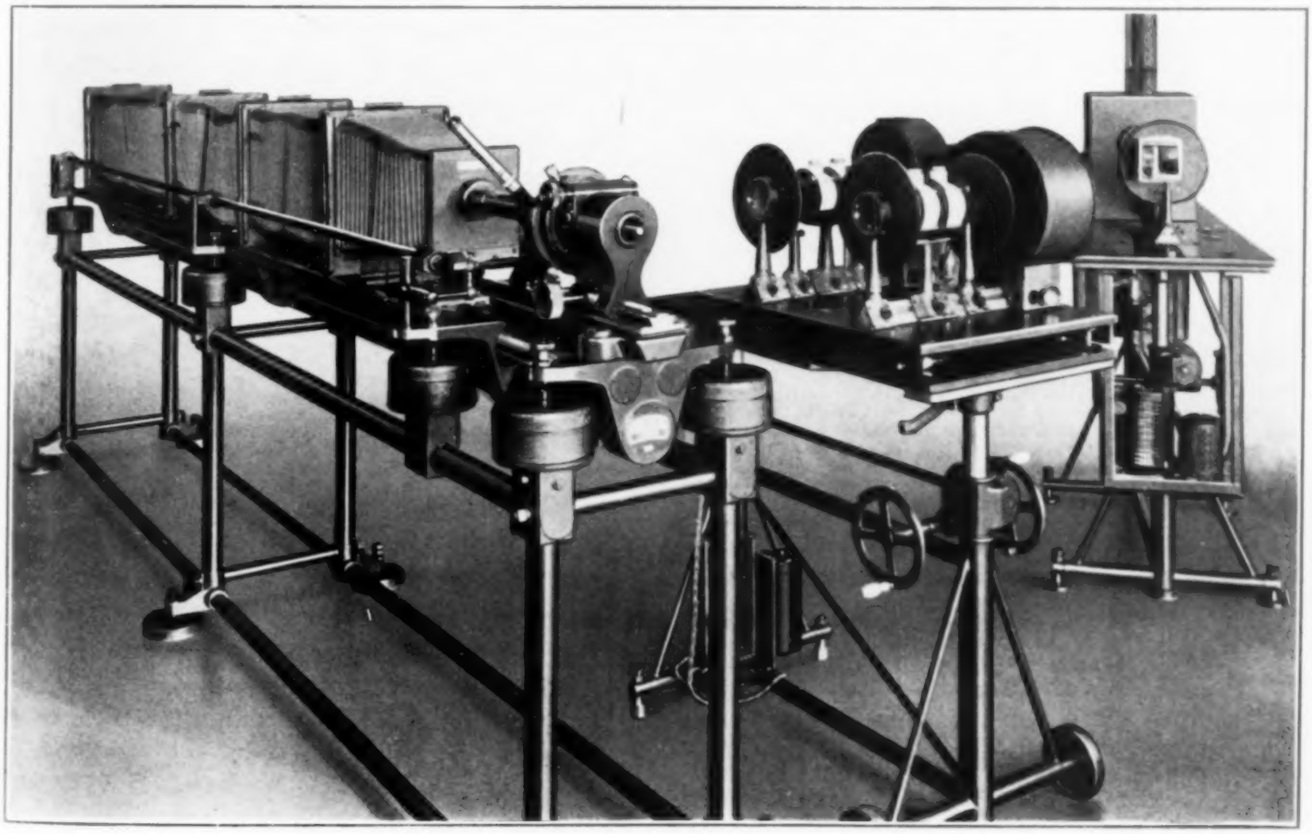
shown in the micrograph reproduced on page 20.

The entire equipment is mounted on three stands as illustrated. Great difficulty would be encountered in eliminating vibration and in freeing the equipment from outside mechanical disturbance if the apparatus were mounted on a single stand. The microscope, stage, and camera are mounted on one stand which has six feet provided with leveling screws, resting on six cast iron disks which in turn are insulated from the floor by sponge rubber pads. The camera and the microscope are assembled on a carrier which consists of three large tubes which at their ends and at two intermediate points are rigidly joined together by massive yokes resting on shock absorbers, a total of eight. The two upper tubes of the carrier serve as rails for the camera.

The camera is in four sections so that, if desired, any length bellows extension may be secured, and each section is provided with a clamping device. The maximum plate size of the camera is 24x30 cm.; this may be reduced by suitable kits to accommodate other plates. Holders and screens slip in from above, an arrangement less likely to induce vibration.

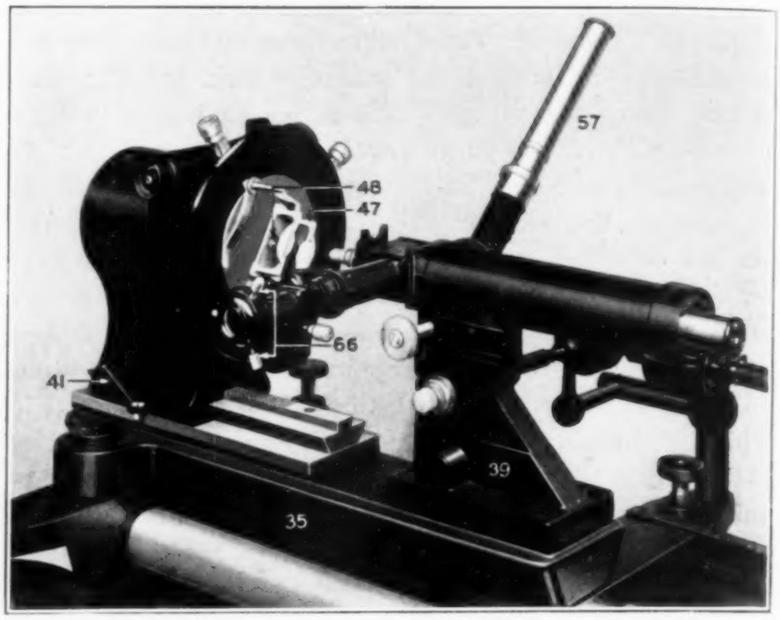
The microscope is arranged horizontally because in the author's opinion the design simplifies construction of focusing mechanism, reduces the number of prisms and optical surfaces to a minimum, is more substantial, and the component parts are less subject to creep. While this arrangement is not quite as convenient to work with as a vertical or inverted type microscope, maximum stability and a minimum number of delicate moving parts are more to be desired than convenience.

A close-up of the microscope from the illuminator side is shown on page 21. The base plate 35 rests, tension free, on three hardened steel balls, properly disposed about the center of gravity of the entire microscope.



Precision High Power Metallographic Apparatus After Lucas Designed and Developed by Bell Telephone Laboratories, Inc., in Cooperation with the Firm of Carl Zeiss, Jena, Germany

The stage, at the left, is massive and separately mounted. It revolves about a long horizontal axis and may be rapidly turned by hand or slowly by a knob. Two thumbscrews permit transverse movement in two directions. The movement is not fixed as horizontal and vertical. As a result an assistant operating the stage moves the specimen diagonally. Experience with the apparatus has shown conclusively that this is a distinct disadvantage, and oftentimes a serious annoyance. In fact, this entire stage could better be built along the lines of a precision machine tool; the stage plate should slide on massive, carefully machined ways, and also be capable of rotation and locking in any position.



Microscope Assembly From the Vertical Illuminator Side

The object is held in special interchangeable holders *47* with surfaces *exactly* parallel to the stage. A holder is selected to suit the dimensions of the specimen; it is then fastened to the stage by two locking screws. The specimen is slipped in back of the parallel surfaces and is held against these surfaces by a single point contact *48* under spring tension. Contact *48* is drawn back by a rod terminating in a knurled knob at the rear of the stage. This method of mounting has been found fully satisfactory.

To the opposite end of the base plate is fastened the tube carrier *39*, provided with conventional coarse adjustment and a standard slow motion. This whole microscope assembly has some unusual features (which cannot be described in this brief abstract). It can carry either the old standard objectives corrected for a fixed tube length of 190 mm., or objectives corrected for infinity tube length — a new development. Actual work with the apparatus seems to have demonstrated conclusively that the infinity corrected objectives are superior and they are now being used exclusively.

The sketch on page 25 shows a very simplified diagram of the optical system of the microscope. The illuminator is fitted with a plain parallel glass plate *8* inclined at an angle of 67.5° rather than the usual 45°. This is the optimum angle for maximum reflection and has an appreciable effect in increasing the illuminating efficiency of the system. The optimum angle of 67.5° for the glass plate would require a change also from a right angle assembly of the illuminating units. To overcome this a small prism *6* is incorporated in the illuminator. The tube of the illuminator contains the lenses and diaphragms regulating the path of rays. (Experience has demonstrated that it would have been desirable to separate the microscope from the illuminator on massive, adjustable ways, and the whole assembly enclosed in a removable metal cover with suitable apertures.)

The microscope tube is provided with an observation tube (*57* in the halftone) which is fitted at its base with a simple reflecting prism (*10* in the drawing). When the observation tube is pressed downward the prism intercepts and deflects the rays on an eyepiece for observation. When the observation tube is withdrawn the rays continue through the main tube ocular *12*, producing the image on the focusing screen or photographic plate.

The use of objectives corrected for infinity and a Keppler telescope has the advantage that the vertical illuminator may be inserted at a place where the rays of light are parallel. The

plane glass plate of the vertical illuminator then reacts alike on all the rays without interfering with their original correction. When using objectives corrected for 190 mm. tube length, the cones of light passing through the plane glass have a finite, though small, aperture angle. The disturbing influence of the plane glass becomes more pronounced the higher its index of refraction and the narrower the angle to the axis.

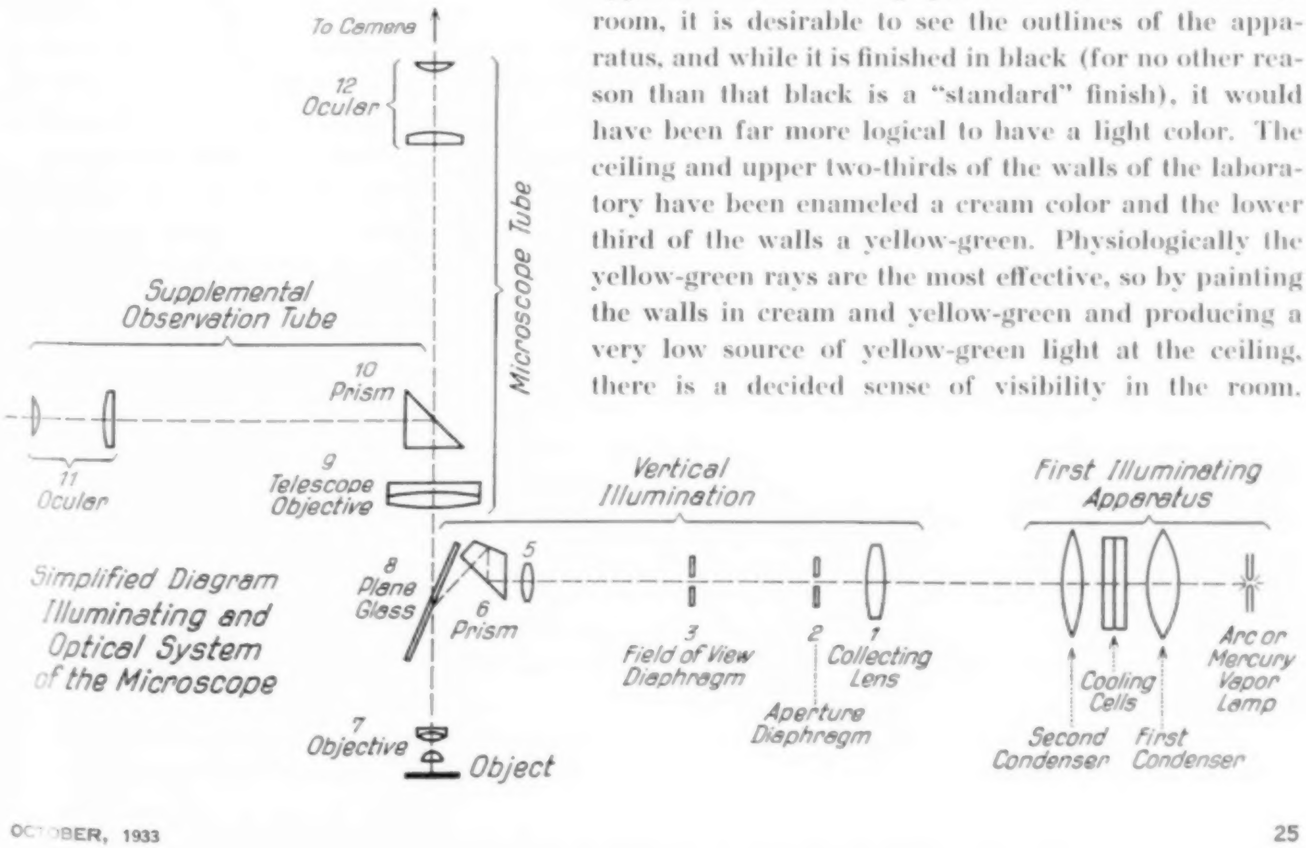
The illuminating stands are shown at the left of the photograph on page 23. They are not safeguarded against outside disturbances, as was done with the camera and microscope stand, because the optical system is so designed that the beams of light cover completely the aperture diaphragm opening.

The illuminating stand placed nearest the microscope carries two parallel optical benches so mounted that when the table top is run to the left until it strikes a fixed stop a beam from an arc lamp is brought into alignment with the vertical illuminator. Moved in the opposite direction, the mercury vapor lamp comes into adjustment.

The arc lamp train is the most intense source of illumination and is used in conjunction with Wratten filters. The mercury vapor lamp train, in conjunction with filters, provides approximately monochromatic illumination.

When the movable table is placed in a midway position the path to the vertical illuminator is unobstructed and the monochromator, shown at the left rear, may be used. It is designed to operate with two sources of illumination — a spark gap or a mercury vapor lamp. The spark gap is covered by a wooden box lined with sheet metal and heavy felt for deadening the noise of the spark. The box has a flexible hose connecting with an exhaust fan and flue to guard against dangerous fumes getting into the laboratory. The optical train in addition to the spark gap apparatus consists of suitable condensers, an adjustable slit and a large hollow prism. All are mounted on a movable optical bench which may be turned through an arc, pivoting directly beneath the prism. The hollow glass prism is filled with carbon disulphide, monochlor-benzol, or other suitable liquids of the required index of refraction. The light emitted by the spark is thus decomposed into the characteristic line spectrum of the metal used as electrodes. By movement of the optical bench through its arc of travel any desired line may be brought to bear on the vertical illuminator and all others excluded. (A spectrometer mounted on a table against the wall provides an accurate control.)

A special laboratory was prepared to receive the apparatus. Since the equipment is used in a darkened room, it is desirable to see the outlines of the apparatus, and while it is finished in black (for no other reason than that black is a "standard" finish), it would have been far more logical to have a light color. The ceiling and upper two-thirds of the walls of the laboratory have been enameled a cream color and the lower third of the walls a yellow-green. Physiologically the yellow-green rays are the most effective, so by painting the walls in cream and yellow-green and producing a very low source of yellow-green light at the ceiling, there is a decided sense of visibility in the room.



Simplified Diagram Illuminating and Optical System of the Microscope

By N. A. Ziegler, Metallurgist, Research Laboratories
Westinghouse Electric & Manufacturing Co.

PURE IRON

WHAT is iron and what are its properties? It would seem that technical people nowadays should have no difficulty in answering this question. Everybody ought to know this metallic element, used by humanity from prehistoric times. Egyptians and Assyrio-Babylonians, about 4000 B.C., knew of iron, could manipulate it and apply it to their needs. In our days it is the most widely used of all metals.

Its priceless property of becoming and staying magnetic puts it in an honorable place in the family of metals. The other two ferromagnetic metals, nickel and cobalt, cannot substitute for it because of their relative scarcity in nature, and because of their low magnetic quality as compared to iron.

Iron enters as the principal constituent in all steels, cast irons, wrought irons, and other ferrous alloys, which play such an important part in the progress of modern civilization. Until very recent times, it was the only metal used for construction purposes. Indeed, without iron all progress of modern civilization, technology and science would be an impossibility, and it is difficult to imagine what course life would take if, for some reason, we did not have iron.

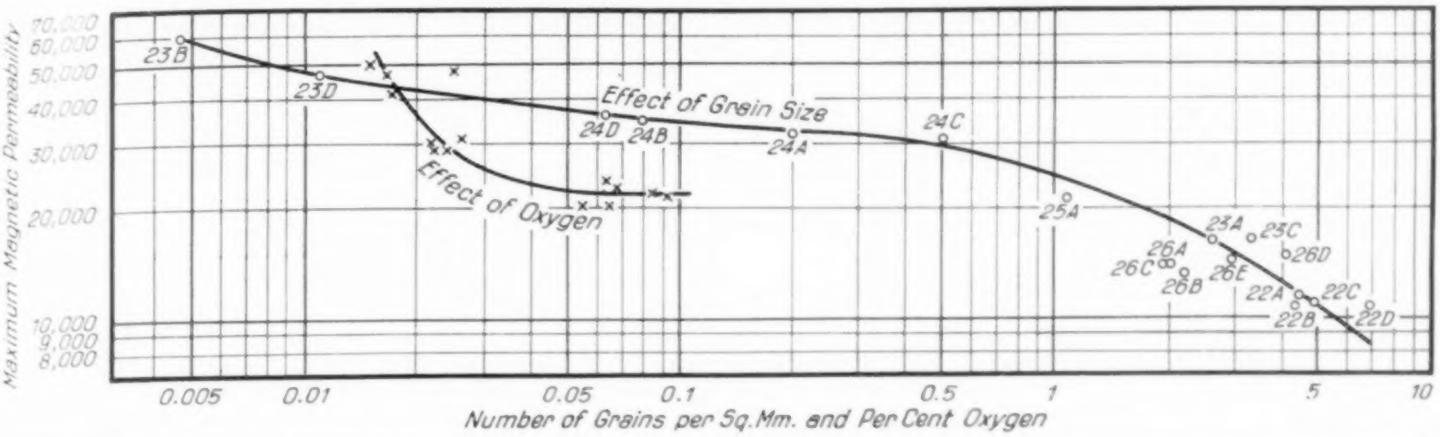
To develop the idea, let us very briefly go over what was understood by the term "iron" at different periods of the world's history.

The earliest iron known to humans was, unquestionably, of meteoric origin. Weapons and tools made of meteorites were in use long before the art of extracting iron from ores came into existence. Undoubtedly, prehistoric men considered meteorites as gifts of the gods, and in imagination, we may picture the celebration in a prehistoric village on the finding of a meteorite. A relic of this reverent feeling towards meteoric iron is the famous Kaaba of Mecca, still worshipped by Mohammedans.

Today we know that all meteorites contain several different ingredients, sometimes up to several per cent, and cannot be considered as pure iron. Hence, a prehistoric man, using in his primitive language the word for "iron," meant something quite different from what a modern metallurgist means.

It was a tremendous accomplishment when iron was first made in what is now known as a Catalan forge. This was one of the most important turning points in the world's history, when iron ceased to be a "god-send" and became a commercial product. We know now that the Catalan forge produced an extremely "dirty" metal. In fact, it is much "dirtier" than meteoric iron, but for several thousands of years it was the most important type of iron.

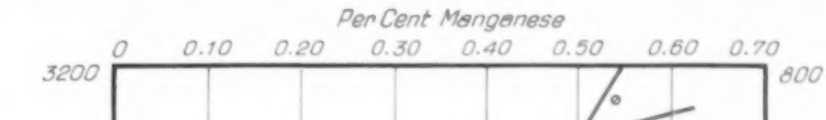
As the Grain Size of Iron Increases and Oxygen Decreases Its Permeability Increases



The next long step was the discovery, sometime during the Middle Ages, of cast iron, soon followed by the appearance of the puddling process for converting it into wrought iron, and of the cementation process used in making steel. Men knew of the close relationship between these three products, and realized that wrought iron was the purest of them. Despite the fact that the microscope shows it to be shot through with slag streaks, for several centuries it was regarded as the purest form of iron, and even today quite a few can be found among old puddlers and blacksmiths, who will say that wrought iron is the purest form of iron that can be obtained.

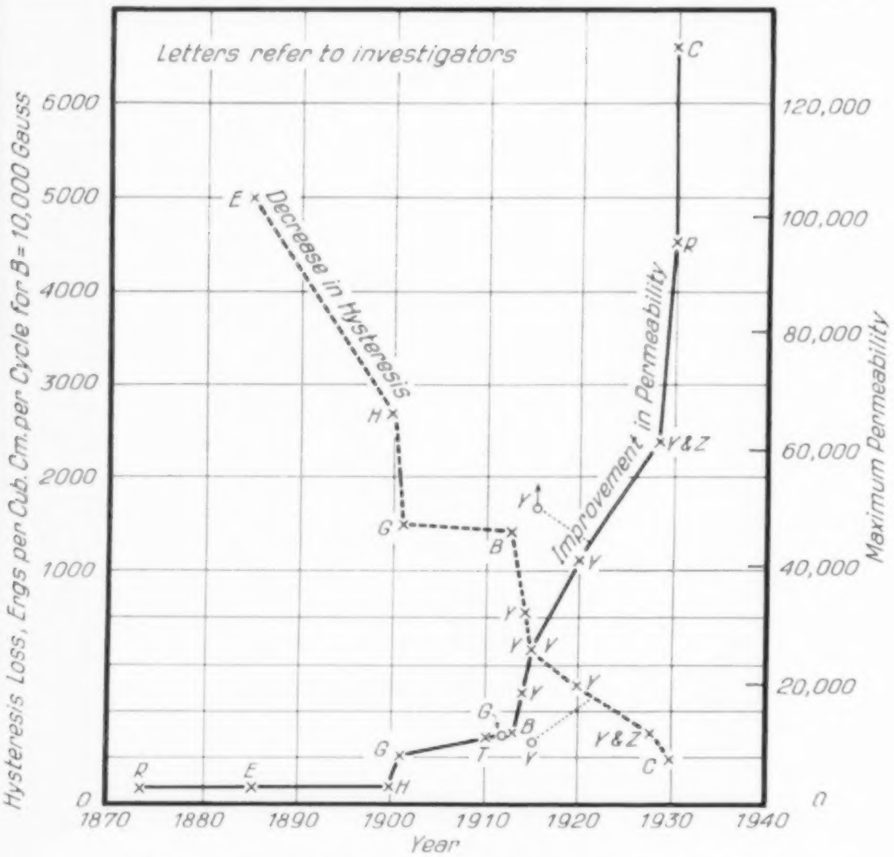
Certain evolution, however, is a geometric progression. Within the last hundred years, we have seen more changes taking place than during the rest of the world's history. Metallurgy is no exception; within the last few decades we have learned to prepare metals of a purity never dreamed of before. While less than two generations ago wrought iron was still the purest form obtainable, today we have electrolytic iron and ingot iron manufactured on commercial scales with only traces of impurities. In the laboratory, we can refine these products still further by vacuum melting and special heat treatments to the point where the most refined chemical analyses can discover only traces of impurities.

Are we justified in calling this "pure iron"? Chemists have told us that iron is one of 92 elements and assigned to it the atomic number 26, leaving its properties largely undetermined. Physicists helped somewhat in this problem, and by means of X-rays determined its atomic structure or space lattice. In their investigations chemists, as well as physicists, were and are using as their working materials products pre-



As the Content of Carbon, Sulphur, Manganese and Phosphorus Decreases, the Hysteresis Loss of Iron Approaches Zero

pared by metallurgists. As a result of the cooperation of these three branches of science, we know (or at least we think we know) that iron is an element with the atomic weight of 55.84; it solidifies at 1530° C.; in the range of temperatures from 1530 to 1400° C. it has a body-centered cubic space lattice; from 1400 to 900° C. it has a face-centered cubic space lattice; from 900° C. to absolute zero it has a body-centered cubic space lattice again; at 780° C. it has a magnetic transformation point, below which it is ferromagnetic, and above, paramagnetic. Other facts might be listed, but those are illustrative.



Efforts to Purify Iron in Recent Years Have Strikingly Improved Its Permeability and Decreased the Hysteresis Loss. Letters refer to investigators who published results in years given

This is all very true about a laboratory product containing about 99.95% iron, plus a little carbon, oxygen, hydrogen, nitrogen, silicon, sulphur, phosphorus, and perhaps some other elements, which all together amount to about 0.05%. The question that we are now asking ourselves is whether or not these 0.05% of "impurities" are sufficient to change radically the properties of pure iron — i. e., 100.000..% Fe.

In other words, are we justified in considering iron containing 99.95% Fe as "pure"?

Some light on this query may be shed by magnetic studies made during the last 20 years by Yensen and his associates in the Westinghouse Research Laboratory.

After an intensive study of different factors affecting the magnetic quality of various alloys (and, in particular, of "pure" iron), the theory has been proposed that anything that distorts the space lattice of an alloy is harmful to its magnetic quality. These factors may be interstitial impurities or colloidal precipitates, strains caused by rapid cooling or mechanical deformations, and interference with the regular course of crystallization where two grains meet to form grain boundaries. Granted that the theory is valid, it follows that an ideal magnetic material would be a single crystal of iron, not deformed even to the slightest degree by outside forces or inside irregularities. Such a material has never been produced, but from what is already known, some properties have been predicted.

In his numerous publications, Yensen describes the effect of different elements and of the grain size on the magnetic properties of iron. In order to determine these relations it was necessary to develop elaborate methods of analyses and new apparatus for determining the presence of the last traces of impurities in alloys.

As a result of these efforts, the effects of different factors on the magnetic quality of iron are now fairly well-known, not only qualitatively, but also quantitatively. The first two curves (page 27) illustrate some of these results. From them it appears that carbon, oxygen, sulphur and manganese increase the hysteresis loss and decrease the maximum permeability of the metal, while the effect of phosphorus is very small. Increase of the grain size reduces the hysteresis loss and improves the maximum permeability.

Naturally, in every alloy the combined effect of all these factors (and sometimes others) come into play, and their separation into the individual components is a laborious task, involving considerable juggling and uncertainty. In view of the fact, however, that when the

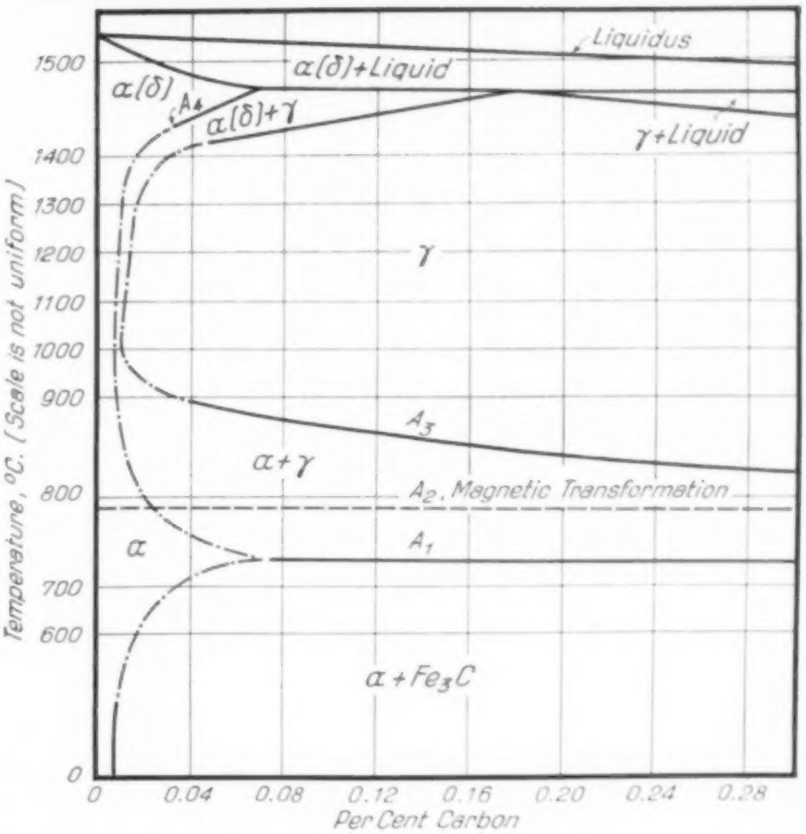
purity and grain size of iron is steadily increased the curves for the hysteresis loss, as a function of these factors, point towards zero and the permeability curves towards infinity. Yensen, years ago, expressed the opinion that a perfectly pure and undisturbed crystal of iron should have zero hysteresis loss, and an infinitely high maximum permeability.

All the experimental results obtained since then support this theory and none contradict it. At present we are approaching the point where our most refined and accurate analytical methods report only traces of impurities present, and yet the variation of magnetic quality in supposedly identical samples of iron is still considerable. In other words, the purer the iron the more effective the remaining traces.

It is also of interest to develop the subject from another angle. If, as has just been shown, impurities and grain size determine the magnetic quality of undeformed iron, magnetic properties may be used as a yardstick in estimating the purity of iron. On this assumption the curves on page 28 are plotted in which the highest maximum permeabilities and lowest hysteresis losses, correspondingly, are plotted for different periods of the last sixty years.

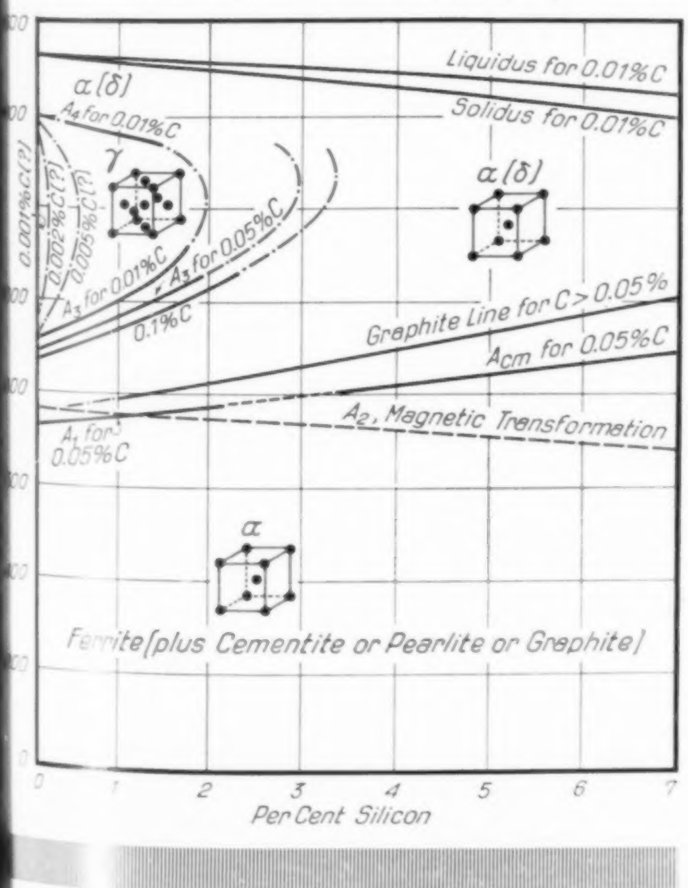
In discussing these curves, Yensen, who published them in 1928 and revised them in 1931, says: "The material used for measuring the maximum permeability and the hysteresis loss of iron in each particular period was regarded at the time as 'pure iron'". In the decade 1880 to 1900 it was Swedish charcoal iron; in 1910 it was electrolytic iron annealed at 900° C.; in 1914 it was electrolytic iron melted in an Arsem vacuum furnace, and vacuum annealed, and in 1928 it was electrolytic iron melted in vacuum in a high frequency induction furnace and vacuum annealed. The "pure iron" of today is electrolytic iron melted either in vacuum or in a hydrogen atmosphere and annealed in hydrogen at high temperatures.

It is clear that within the last thirty years the maximum permeability of "pure iron" has been increased about 40 times, due to a corresponding improvement in purity. But this does not mean that we are justified in saying today that we can make pure iron, because if in a year from now we shall be able to double the maximum permeability, as is probable, it follows that the purity must have been increased correspondingly. *(Continued on page 68)*



Hypothetical Constitutional Diagram for Pure Iron Alloyed With a Very Little Carbon. Horizontal scale much enlarged. (Yensen)

Constitutional Diagram for Iron-Silicon System (Yensen)



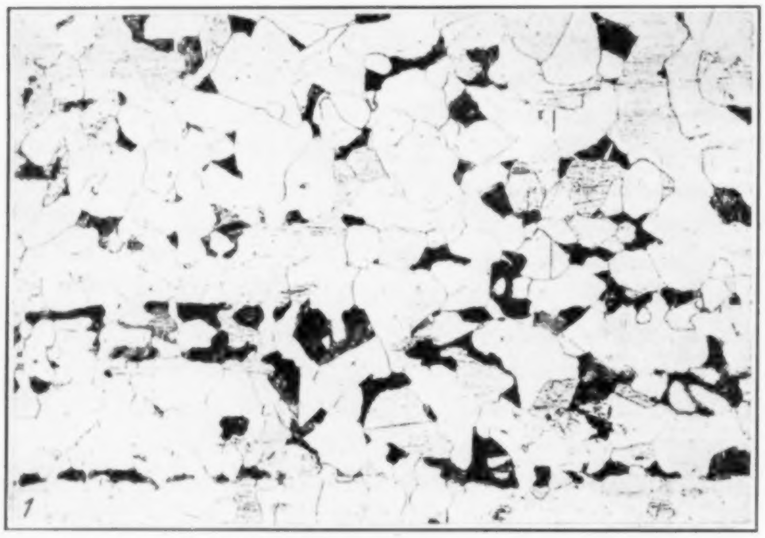
By M. A. Grossmann, Research Engineer
Illinois Steel Company, South Chicago, Ill.

GRAIN SIZE AND GRAIN GROWTH

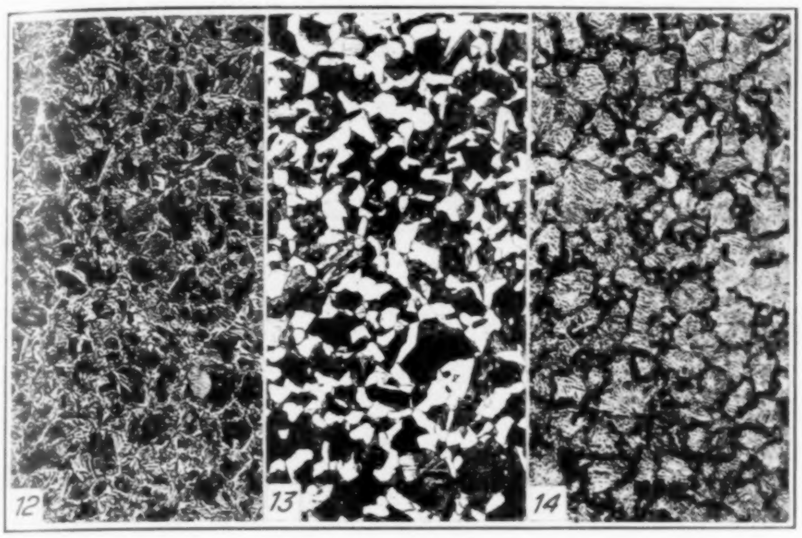
Extracts from a Paper for A.S.S.T. Convention

AMONG the kinds of grain size studied in steels, an important one is the austenite grain size of a piece of steel about to be quenched (hardened). In seeking to determine this austenite grain size, the method commonly employed is the well-known McQuaid-Ehn test. On any particular heat (melt) of steel it gives about the same result—irrespective of any cold work, hot work, or heat treatment that may have preceded this test—with a frequency that makes the exceptions the more striking.

It is useful to examine first the formation of austenite in the absence of carburizing in a plain carbon steel of the "carburizing" grade, No. 1 of the table, page 34. Specimens were cut from 5x5-in. billets which had been rolled from 21-in. diameter ingots. The steel before treatment had the customary grains of ferrite and islands of pearlite as shown in Fig. 1. Given a McQuaid - Ehn test, the steel showed the grain size illustrated



Original 5x5 in. Billet of Low Carbon Steel, Etched With Nital, and Same After Carburizing 8 hr. at 1700° F. (Ground at 15° to Surface to Afford a Larger Area of Case for Examination) and Etched With Sodium Picrate. Magnified 100 diameters



Steel No. 1, Treated to Determine Grain Size in Austenite. × 100. Fig. 12 has been heated to 1580° F. and quenched in oil. Fig. 13 has been heated to 1675° F., placed for exactly 3 min. in another furnace at 1400° F., then quenched in water. Fig. 14 has been heated to 1600° F., quenched in water, and austenite grains outlined with a special picric acid stain

in Fig. 2. Our present question is, then: "By what process did the low carbon structure of Fig. 1 develop into the high carbon structure shown in Fig. 2?"

Transformation of the pearlite-ferrite structure into austenite may be traced by means of a gradient heating, followed by quenching. In the present instance, one 6-in. length of the steel was heated in such a way that one end reached 1315° F. and the other end 1580° F. A second 6-in. length covered higher temperatures up to 1700° F. They were then quenched in oil and prepared for the microscope.

The first change observed was the formation of a small grain of austenite here and there within a pearlite island. Evidence that each such area is a single grain appears when the grain has grown a little further. A martensitic pattern extends across the whole of the transformed area.

Up to this point the transformation has taken place principally in the pearlite regions. At slightly higher temperatures, austenite begins to encroach into the ferrite grains, the typical manner of encroachment being along roughly parallel paths from the boundaries inward. The transformation proceeds with increasing temperatures until the piece is completely transformed to austenite.

We may now turn to our chief interest — the size of what were the austenite grains, as indicated by their borders and by the extent of the Widmanstätten patterns (Fig. 12). It is important to note that the size of these austenite grains in Steel No. 1 shown on this page is not unlike that of the original ferrite grains of Fig. 1. Further, this grain size (about No. 6) remained unchanged up to nearly 1700° F.

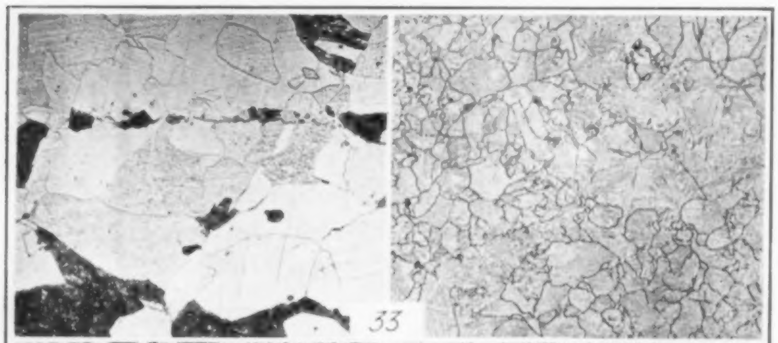
Since there might be some question whether this really indicates the size of the austenite grains from which this structure was formed, two additional devices were employed in seeking to learn the austenite grain size. *(a)* When ferrite is precipitated from austenite in an interrupted quench, it precipitates first at the grain boundaries of the austenite (Fig. 13). *(b)* Perhaps the most convincing manner of indicating the austenite grain size was a new method developed by Miss M. Baeyertz. It consists in suitably quenching the specimen in water and subsequently treating the polished section with a special picric acid stain. Fig. 12, 13, and 14 represent the concordant results of the three methods specified. All are about size No. 6.

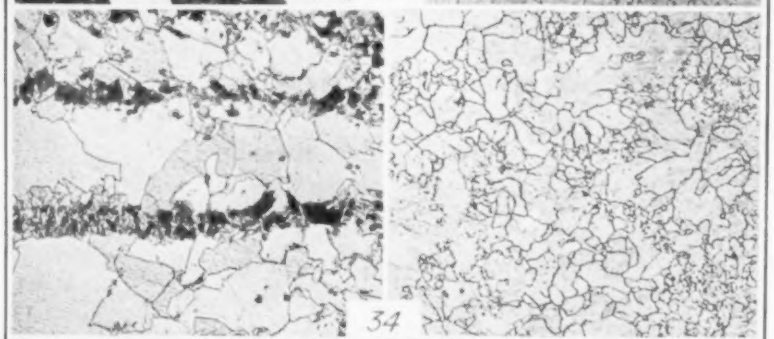
This grain size remains unchanged even after heating 4½ hr. at 1675° F. At 1700°, in this particular steel, a change sets in. After heating for 8 hr. some new large austenite grains have formed (which grow by spreading across the small No. 6 grains which were present before) and occupy perhaps 15 to 20% of the total volume. If the heating temperature (still in the absence of carburizing) is raised to 1800° F., the grain growth is much more rapid, so that 20% of the volume is occupied by the large grains after only 1½ hr., and in 8 hr. the large (No. 1) grains will constitute practically the whole structure.

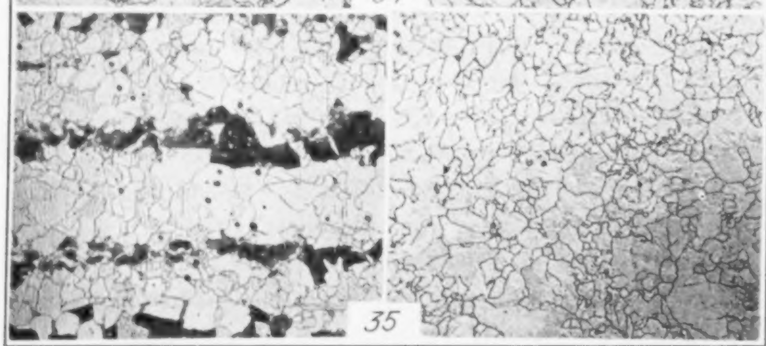
We have just stated that after a simple heating of 8 hr. at 1700° F. about 20% of steel

No. 1 is coarse grained and the remainder fine grained. But Fig. 2 shows that in the *carburized* zone as much as 80% is coarse and only 20% is fine. This is a very marked disparity in grain size between the carburized zone and the uncarburized portion. At this particular temperature, in this steel, the austenite grain size in the case is much larger than in the core.

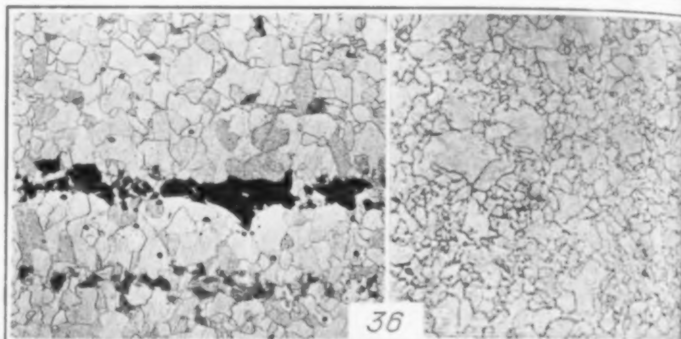
We therefore examined the development of grain size of this steel as carburized at different temperatures. At low temperatures, such as 4 hr. at 1600° F., the grain size of core and case is alike and is the same No. 6 as obtained in the uncarburized steel as soon as it was heated above the transformation range. When the carburizing temperature is raised to 1650° F., however, coarse grains begin to develop in the carburized portion, so that at the end of 8 hr. the structure contains about 15% of coarse

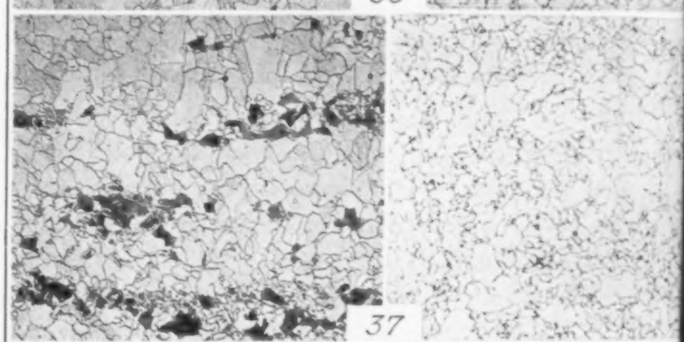


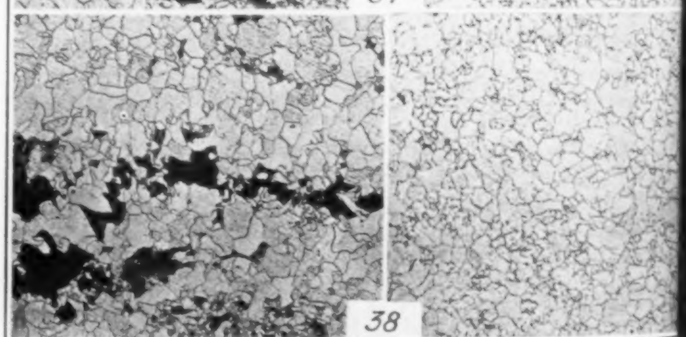




grains. If the carburizing temperature is raised to 1675° F. the rate of growth increases, so that at the end of 8 hr. the carburized zone is about half coarse grains. It will be recalled that at this temperature the uncarburized steel still consisted wholly of fine grains — no coarsening had as yet begun in the absence of carburizing. As the carburizing temperature is raised, the rate of coarsening increases, so that after 8 hr. at 1725° F., the carburized zone consists almost wholly of No. 1 grains.





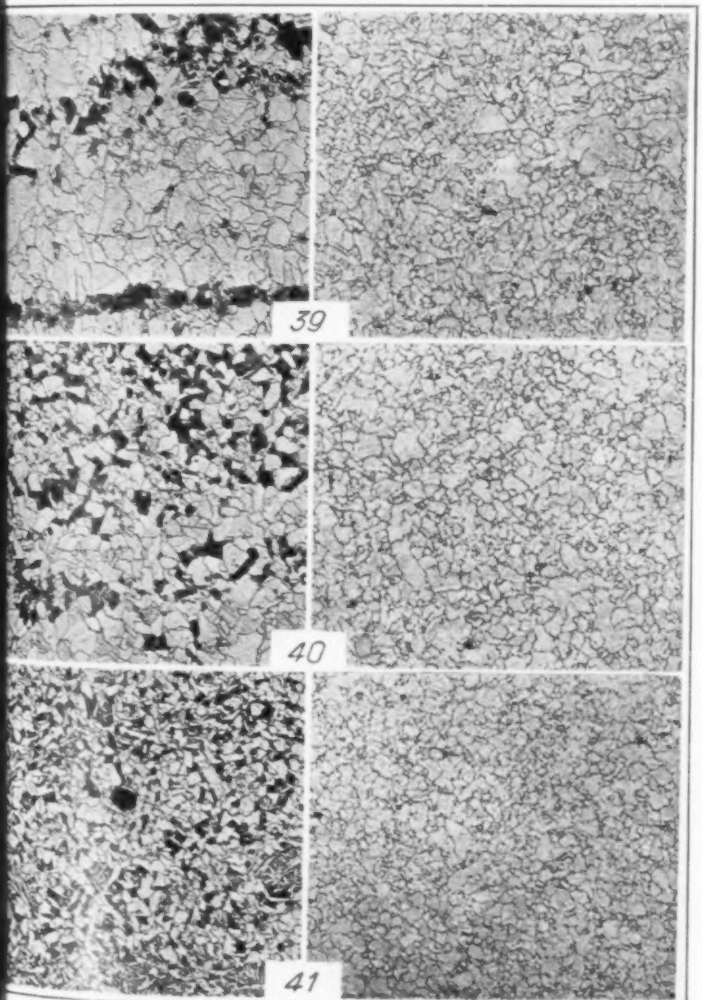


From such experiments it is seen that in this particular steel the formation of coarse grains in the carburized portions occurs at temperatures at least 50° F. lower than in the uncarburized portions.

Obviously, this leads to speculation in regard to the general behavior of plain carbon

steels. A group of eight steels was therefore carburized at a series of temperatures. The compositions of the steels are given in the table on page 34 and the (austenite) grain sizes as judged from the carburized zones after carburizing at the various temperatures. From these figures one is led to the important conclusion that at temperatures at which coarsening (exaggerated grain growth) takes place, the time and temperature of carburizing affect the results; but in the temperature range where exaggerated grain growth *fails* to take place (which not infrequently extends up to 2000° F.), the steel may be carburized at any temperature and for any length of time, and the grain size will remain precisely the same — the size formed when the steel first transformed to austenite.

The next step is to study some factors affecting this initial austenite grain size.



Nickel-Molybdenum Steel Heat Treated to Refine Ferrite Grain (Left Hand Micros) and Then Carburized. Micros of cases (at right) are etched with sodium picrate. × 100. All photographs are by H. C. T. Han

Consider an instance of carburization where no exaggerated grain growth took place, that is, a steel which when carburized at 1700° F. behaved as did plain carbon steel No. 1 when carburized at 1600° F. An instructive example was found in a heat of nickel-molybdenum steel No. 9 of the following composition: C 0.17%, Mn 0.51%, P 0.007%, S 0.004%, Si 0.22%, Ni 1.68%, Mo 0.23%, Cr 0.07%. Its structure, as received and after carburizing 8 hr. at 1700° F., is shown in Fig. 33 (grain size No. 5).

If this steel is heated to 1700° F. without carburizing, it is seen to exhibit a grain size of about No. 5. After carburizing at 1700° F. for 1, 3, and 6 hr. respectively, the size remained unchanged. It is evident that the grain size established in the core determines the grain size in the carburized region.

This steel No. 9 was likewise explored to discover the temperature at which exaggerated grain growth took place. At 2100° F. it still displayed grain size No. 5, but at 2150° F. it underwent substantial coarsening.

Now as to the initial austenite grain size: Reference has already been made to the fact that McQuaid-Ehn grain size is often independent of prior heat treatment, but that there are exceptions to this behavior. Steel No. 9 is one of these exceptions. The circumstance which led to the present inquiry was the observation that the McQuaid-Ehn grain size of this steel after normalizing was smaller than was obtained if the normalizing was omitted. In seeking a cause for this behavior it was found that samples with smaller ferrite grains before carburizing gave smaller McQuaid-Ehn grain size.

An obvious next step was to ascertain if there was any regularity in this relationship. For this a series of ferrite grain sizes was obtained by heating samples from the original billet numbered as follows:

16-N Heated to 1600° F., cooled in air.

17-1 Heated to 1700° F., cooled in air.

17-2 Heated to 1700° F., cooled in a 3-in. box in air.

Grain Size of Low Carbon Steels After Carburization

Steel No.	Chemical Composition					Grain Size After 8 Hr. Carburizing			
	C	Mn	P	S	Si	1700°F.	1800°F.	1900°F.	2000°F.
1	0.15	0.44	0.015	0.019	0.22	85% No.1 15% No.6	No.1	No.1	No.1
2	0.15	0.46	0.015	0.017	0.16	No.1	No.1	No.1	No.1
3	0.12	0.37	0.011	0.025	–	No.6	30% No.1 70% No.6	85% No.1 15% No.6	No.1
4	0.14	0.79	0.011	0.017	0.28	No.6 to No.7	No.6 to No.7	No.6	No.6
5	0.17	0.79	0.009	0.014	0.29	No.5 to No.6	No.5 to No.6	No.6	No.6
6	0.14	0.80	0.008	0.016	0.22	No.6	No.6	No.5 to No.6	No.6
7	0.15	0.38	0.011	0.017	0.21	No.1	No.1	No.1	No.1
8	0.18	0.78	0.010	0.018	0.24	No.6 to No.7	No.6 to No.7	No.6	No.5 to No.6 with few No.1

17-3 Heated to 1700° F., normal furnace cooling.

17-4 Heated to 1700° F., delayed furnace cooling.

19 Heated to 1900°, cooled with furnace.

21 Heated to 2100°, cooled with furnace.

23 Heated to 2300° F., cooled with furnace.

15 Heated within critical range, air cooled.

1 Original billet.

These pieces were thereupon carburized, and when the samples were then placed in the order of decreasing McQuaid-Ehn grain size, they were found to be arranged as follows: 1, 15, 23, 21, 17-4, 19, 17-3, 17-2, 17-1, 16-N. This was almost precisely in the order of decreasing ferrite grain size before carburizing, as will be seen by examining Fig. 33 to 41, which are arranged in the series just noted (except for sample 17-2, which is missing). At the left in each case is the structure before carburizing, and at the right is the structure in the hyper-eutectoid zone after carburizing. It will be observed that as the prior ferrite grain size changed from No. 1 to No. 8, the subsequent McQuaid-Ehn grain size changed from No. 5 to No. 9.

Fine Grain Persists

One seems warranted in concluding, therefore, that in some steels the McQuaid-Ehn grain size is influenced by any prior heat treatment which changes the ferrite grain size. And, at the same time, this suggests a reason why cold work sometimes leads to a finer McQuaid-Ehn grain size: Obviously, it may break up larger ferrite grains.

Attention may now again be directed to the fact that this relationship between prior ferrite and subsequent austenite exists here in the absence of exaggerated grain growth. One may well ask what happens when exaggerated grain growth takes place. If samples of this same steel are carburized at 2150° F. for 8 hr., exaggerated grain growth takes place in either fine-grained or coarse-grained samples, resulting in both cases in a preponderance of No. 1 grains, with a few of the smaller grains still unabsorbed (an experiment first carried out by L. Schapiro). And this, of course, raises a question yet to be answered: Are the steels whose McQuaid-Ehn grain size is independent of prior treatment the ones in which exaggerated grain growth takes place in carburizing at 1700° F.?

There are some steels for which 1700° F. is apparently just the temperature at which exaggerated grain growth begins. In such steels grains begin to grow at isolated regions throughout the steel, and continue to grow but slowly during the whole course of the 8-hr. carburizing period. The result is a structure which has sometimes been termed "mixed grain size."

Every steel has a coarsening temperature which, if exceeded, causes coarse grains (No. 1 to No. 2) to form. If the carburizing temperature is above the coarsening temperature, the final carburized piece will consist partly or wholly of coarse grains. But if the carburizing temperature is at any temperature below the coarsening temperature (and the latter may be high, even above 2000 or 2100° F.), then the austenite grain size will remain unchanged, precisely what it was when the steel first transformed to austenite upon heating.

In some steels this initial austenite grain size is related to prior ferrite grain size and is in these cases affected by prior heat treatment.

By A. E. R. Peterka, Metallurgical Engineer
Lamson & Sessions Co., Cleveland

COLD FORMING THE STAINLESS STEELS

SCREWS, bolts and nuts are generally referred to collectively as "fasteners" and shall be referred to by this term in the following discussion. There are three common means of making fasteners, depending largely on their size, shape and the quantities involved in ordinary production.

One method consists of milling from the bar on automatic or hand screw machines. The chief objection to this method for stainless steel is additional cost, due to the comparatively large amount of raw material cut away and scrapped. Unlike the brasses and bronzes, the spread between the cost of stainless steel raw material and the scrap value of stainless steel turnings is quite large. For this reason fabrication by milling is not economical if hot or cold forming can be utilized.

The second method is that of hot heading. Headed stainless steel bolts of a difficult shape, ½ in. in diameter and over, and all headed bolts ¾ in. in diameter and over, are made by hot forming. This very useful process will not be discussed at present.

The third method, which is the subject of this paper, is that of cold heading or upsetting and cold punching. This is considered the most economical for the smaller sizes of fasteners because, theoretically at least, every bit of raw material is consumed in the cold heading operation except the small amount cut away in slotting the head or shaving, where these operations are required. Cold punching of nuts saves the cost of heating and a further economy resulting from greater production as compared to milling from the bar.

Since the raw material is usually the main item in the cost of stainless steel fasteners, it should be quite obvious that the cold forming method of fabrication is the most economical where the design of the product permits.

Selection of Materials

Where sheets or parts of a certain grade of stainless steel are to be fastened together, fasteners of the same material are usually employed, in order that the entire unit have the same corrosion resistance and appearance (finish and color).

When only the fasteners are to be of corrosion resistant alloy, it becomes necessary to

determine which grade will meet the conditions most economically. The three types commonly used are given in the order of their price: Most expensive is the 18% chromium, 8% nickel steel, next is 16 to 18% chromium-iron alloy, and cheapest is the 12 to 14% chromium steel.

At the present time the straight 16 to 18% chromium type, with its variations, seems to be enjoying the greatest popularity, owing to its broad utility and comparative ease of fabrication by cold forming.

Due to the drastic deformation encountered in cold forming, it is very important that the raw material (wire) shall be as free from seams and other surface defects as the best commercial practice can provide. Any seaminess will usually show up by the heads of the bolts cracking in the heading operation.

Wire for cold heading is usually provided with a coating by the wire manufacturer to act as a lubricant in the dies. There are various coatings used, each a deep dark secret with their manufacturer; basically they consist of a film of oxide and lime or soap and tallow. In some cases a coating of copper is plated on the wire, and this acts as a lubricant. However, if the coating provided on the wire should not entirely prevent dragging in the dies, an application of white lead mixed with linseed oil will usually clear up the trouble.

The stainless steels are more resistant to cold deformation than the ordinary steels, requiring 30 to 40% more energy to move them. For this reason any play in the headers will be exaggerated and careful alignment of machinery is required.

Neither the manufacturers of stainless steel wire nor the bolt makers seem to agree on any comparison between the susceptibility to cold heading of stainless steels and S.A.E. 1020 steel, for example. Our experience is that as a group these alloys are about 70% as readily headed as common steel. This difference shows up in the tool life and in the ability to fill out difficult head shapes and produce sharp corners.

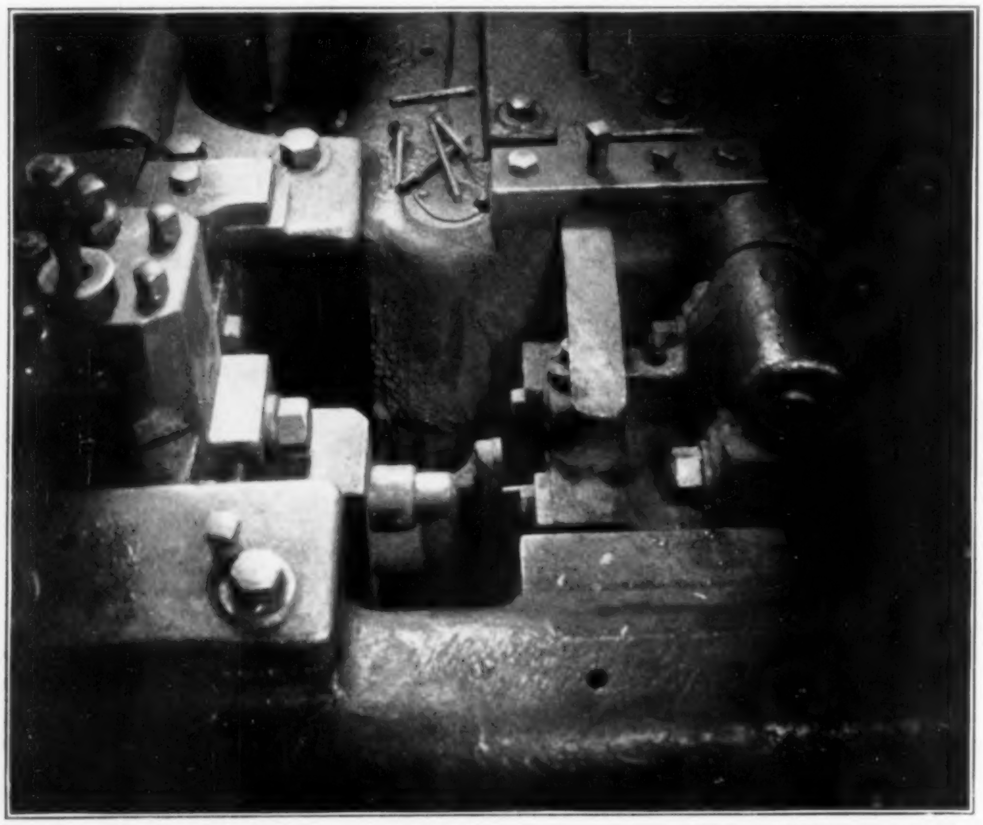
It is good economy to use dies and hammers made from the best die steels, carefully heat treated. At best one may expect about 70% of the life of these tools when heading stainless steel, as compared with similar work on ordinary steel. Solid dies should be used where possible, but when open dies must be used it is desirable to lap them.

When setting up for a job it has been found economical to do so with regular steel wire. In this way the scrap produced is cheap steel rather than the high priced stainless steel wire.

Stainless steel wire used for cold forming has a low carbon content, usually 0.08 to 0.10% and rarely over 0.14%, and with the exception of the 12 to 14% chromium grade is not susceptible to hardening by any known heat treatment. Heat treatment or annealing is therefore for the purpose of relieving heading strains and increasing the corrosion resistance. It is desirable to follow the heading operation with the heat treatment, thereby facilitating the subsequent operations such as slotting and threading.

Recommended practice is as follows:

Looking Down Into Jaws of Heading Machine



Heat Treatment

No heat treatment is required for simple upsets in 12 to 14% chromium steel parts up to 1/8 in. diameter. Over that size the fasteners should be heated to 1750 to 1850° F. and cooled in air.

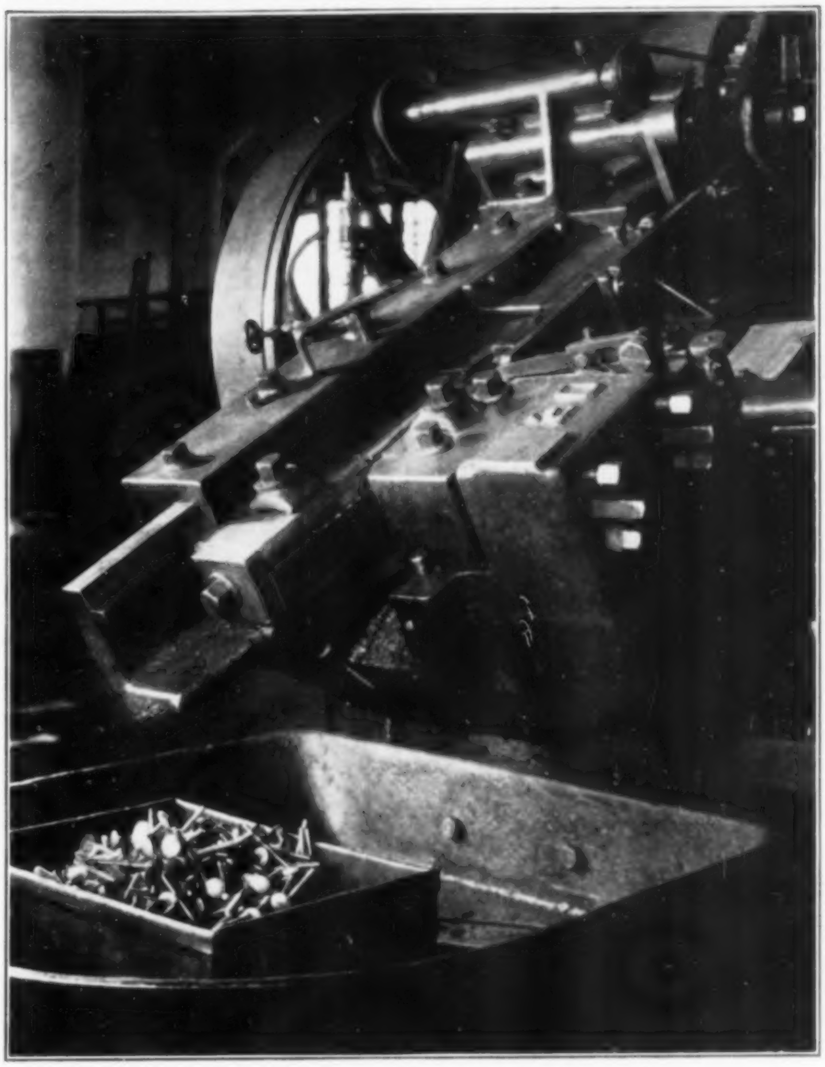
No heat treatment is required for simple upsets in 16 to 18% chromium-iron parts up to 3/16 in. diameter. Over that size the fasteners should be air cooled from 1300 to 1350° F.

All sizes of 18-8 fasteners or other parts which have been cold upset or cold punched should be water quenched from 1750 to 1850° F.

Grease and dirt should be removed from the material before heat treatment, in order to avoid carburized spots on the surface which might subsequently corrode.

Pickling is next in order. There are several satisfactory solutions for pickling. A 50% solution of hydrochloric acid at 160 F., or a 10% sulphuric acid and 10% rock salt solution at 180° F. are frequently used. Material should be rinsed in water, dipped in 30% nitric acid and washed again after pickling in any of the above solutions.

Practice at Lamson & Sessions' plants is to use a 40 to 50% nitric acid solution at room temperature. This will loosen any adhering scale or coating sufficiently to leave the material bright and clean after water tumbling. It is also the same solution used later for passivating.



Roll Threading Strengthens an 18-8 Bolt or Screw Since All Austenitic Steels Harden Rapidly During Cold Work

Stainless steel fasteners are given a soap water tumble in a tumbling barrel to remove loose surface particles and to polish. Bolts over 1/4 in. diameter are given no further polishing except where wheel polishing and buffing may be specified.

Bolts under 1/4 in. diameter are subjected to another soap water tumbling after the passivating operation to improve their polish. This tumbling will not injure the threads of these smaller sized screws and improves the appearance and corrosion resistance.

Slotting of screws made from the straight chromium alloys is done at the same speed employed for regular steels. No difficulty should be experienced with slotting if saws of high speed steel with fine teeth of ample rake are used, and if the saw is not permitted to ride on the surface of the metal.

With 18-8 the problem is more difficult, and even if all the above precautions are observed it is found that the slotting speeds must be reduced by about 50%.

Roll Threading

For screws requiring only a simple upset, but also shaving, slotting and drilling, it is often found desirable to sacrifice some of the upsetting qualities for machinability by using the free machining grade of alloy.

About the only important difference be-

tween cut threading stainless steel and ordinary steel is that it is desirable to use a cutter with four or five thread lead on stainless steel instead of the ordinary two or three lead.

The low carbon stainless steel alloys are not hardened by heat treatment but their tensile strength and hardness is increased by cold working. For this reason rolled thread stainless steel screws have a harder thread and a better tensile strength than the same size screw with a cut thread.

Experience has taught us to avoid roll threading dies of plain carbon steel. Dies made from plain carbon steel or improperly heat treated alloy steels will quickly crumble and ruin the threads. Even if such dies are changed before producing seriously defective threads, they will leave behind tiny particles of die steel deeply imbedded between the threads and these particles will rust badly after the product gets into service.

On a commercial basis, $\frac{3}{8}$ to $\frac{1}{2}$-in. nuts are about the largest which may be economically produced from stainless steel by cold punching. These limits depend on the type of equipment available, but it can readily be perceived that the investment required for special machinery which could cold punch a 1-in. nut from stainless steel would not be justified by the saving over hot forming or milling from the bar.

When cold punching nuts from stainless steel it is necessary to keep a close neat fit or clearance between the punch and die. If the clearance is too great the metal will be drawn over the edge and become work hardened to such an extent that excessive strain will be put on the tools and press. Special punches must therefore be procured.

Another point to keep in mind when punching stainless steel, particularly 18-8, is to punch the holes a little larger than the nominal size of hole for tapping. The reason for this is that these alloys have a tendency to flow and if the holes are not a little larger than in ordinary steel, many taps will be broken.

Need for Passivating

In the course of manufacture the stainless steel nuts and bolts come into close frictional contact with high speed and carbon steel tools, with the result that small particles of these may adhere to the surface of the product. When put into service these particles would rust. Such an occurrence is indeed embarrassing to the manufacturer and in order to avoid this rusting it is necessary to passivate or immunize.

This is accomplished by immersing the material in a 10 to 20% solution of nitric acid at 140° F. for about 20 min., or in a 40 to 50% solution at room temperature for one hour. The latter is more practical because in addition to serving the purpose satisfactorily, no expensive heating equipment and exhaust hoods are required, and the same solution and equipment is used for pickling the material.

Ordinary 20-gal. earthenware crocks are used for acid containers. The fasteners are immersed in long handled wooden or stainless steel wire mesh baskets.

After passivating, the material is thoroughly rinsed, first in cold water and then in hot water, and finally dried in a centrifuge.

Handling and Inspection

Care should be taken that stainless steel materials are not placed in ordinary steel shop boxes or tote pans, especially if they are wet, because rust, forming on the container, will foul the stainless steel. There is also the additional possibility that stainless steel products may become mixed with similar ones of ordinary steel. Therefore, it is advisable that specially designed shop boxes (preferably cadmium plated) be provided for the special alloys.

A modification of the Preece test, used for testing hot galvanized material, will determine whether or not the stainless steel material has been properly and sufficiently passivated. This test consists of immersing the finished material in a copper sulphate solution for about two minutes. Any particles of steel other than stainless steel will become coated with bright red copper, which is readily discernible.

This method can also be used to distinguish between stainless steel and ordinary steel if the parts become mixed. By immersing the material in a copper sulphate solution for two minutes and then drying, it will be found that all the regular steel parts have a copper coating, while the stainless steel retains its bright white color.

EDITORIALS

Valves Vs. Hot Gases

THE somewhat standardized allusion to the perennial race between armor plate and projectile may well be replaced with another having to do with the development of exhaust valves for gas engines. It almost seems that no sooner has the metallurgist produced a material that will stand the gaff than the engine designer, the gasoline manufacturer, or the motor operator comes through with some improvement that restarts the search for a better metal.

In the distant days of 30 years ago, when the automobile first started chugging up and down city steets, ordinary carbon steel was used for exhaust valves. What if the valves did burn out in a few thousand miles! So did tires, and a lot of other replacements at frequent intervals were accepted as a matter of course by the auto enthusiasts.

Motor temperatures gradually increased, however, and before long a 3½% nickel steel ruled the favorite until it was discovered (possibly by Henry Ford — at least it is worthy of him!) that common cast iron was good enough. Cast iron is not essentially a heat resistant material, nor a shock resistant material; nevertheless a cast iron head welded to a steel stem was used by many automotive engine builders until not so many years ago and it served reasonably well.

Airplane engines are another thing. During the War exhaust valves were made of high speed steel — exceedingly expensive, what with the shortage of tungsten, yet nevertheless about the only material that would stand any length of time at the high temperatures which were at last being reached. Stainless steel of the cutlery type, then being produced in England, was generally thought to give somewhat better service for a longer time, and was used abroad for aircraft engines.

Since 1919, many valve troubles have yielded to steels of the "silcrome" type (high in chromium and silicon). They do not change during long heatings and many of them. They have a stable surface to resist hot exhaust gases. They have good toughness and sufficient strength at operating temperatures. All together they seem to be just about ideal for temperatures no higher than 1450° F.

During this time, too, such alloys have been almost universally used in automobiles. One has 9% chromium, 3% silicon, with or without 1½% tungsten. The other is a less expensive steel, containing about 3% chromium, 1% silicon. As a matter of fact, the latter steel is probably near the safe limit for automobiles operating at moderate speed. In the average car of 1930 vintage the exhaust valve rarely operates over 1450° F. and stresses and corrosion are moderate. Furthermore, a slightly

damaged valve, which does not seat properly, will cause negligible motor trouble.

It is different with heavy-duty bus, truck, and tractor; their engines have much higher power output, the valves go up 150° hotter, and the scaling and corroding actions are greatly accelerated. Generally, these conditions may be satisfactorily met with the higher alloy silicon-chromium (9% chromium, 3% silicon, 1½% tungsten) and with austenitic chromium-nickel steels.

In airplane engines of today the conditions are even worse, for temperatures go as high as 1600°, speeds and stresses are high, the safety factor must be high and the useful life as long as possible. Apparently the limit of scale resistance and permanence of physical properties, even of the high chromium, high nickel austenitic steels, has been reached, and the alternative is to cool the valves. This is done either by inserting a copper core, or by putting a little metallic sodium in the hollow stem (it melts and sloshes back and forth, carrying heat from the head down into the stem, where it is drawn off through the guide bushing).

Valve steels seemed to have the better of the argument, but only temporarily. Scaling troubles, almost entirely eliminated by silicon-chromium steels, are now back again since gasolines have been doped with tetra-ethyl lead. Products of combustion of an anti-knock compound are much more corrosive than those from clear gasoline.

Thus the battle between valve steels and exhaust gases once more hangs in the balance. Much research is under way, not only on steels but on fuels and engine characteristics. Austenitic valves with high nickel content appear to be most resistant to corrosive gases from doped fuel, especially when every effort (by internal cooling and proper design of bushing) is made to keep the temperature of the head as low as possible.

Extremely high speeds in supercharged engines using heavily doped fuel of rather poor quality — this combination of requirements of modern aircraft engines probably points the way that motor cars will eventually follow. Altogether they set up a combination of conditions that reduce even the best of our present valve steels to "borderline" performance.

A Tougher Chromium-Iron Alloy

A PAIR of recent announcements from those indefatigable researchers into the alloys of chromium, Union Carbide and Carbon Research Laboratories, does much to clear up an anomalous situation with regard to the chromium-irons with 16% chromium and more. It also achieves its result in a way predictable by the laws of physical metallurgy.

This refers to the fact that the very alloy most useful to the chemical industry is variously reported as too brittle for any good use, and as amply tough even for the manufacture of rivets. Even its best friends, however, readily admit that the alloy solidifies in the ingot or casting with very large crystals of ferrite, and its composition is such that this is a stable phase at all temperatures. Hence heat treating will not refine the grain. The result is leaky castings, or laminated plates or bars — all because the grain is coarse and cannot be broken up except by control of the rolling temperatures.

A couple of years or more ago an English investigator reported that the high chromium alloys were able to absorb an unusually large amount of nitrogen. That led to a systematic study of the effect of nitrogen on the chromium-irons. The easiest way to vary the nitrogen was by using ferrochromes of different nitrogen content, and when experimental heats were made in this way a number of them had unusually fine grain.

Nitrogen now joins the family of elements that "seed" the crystallization of metallic substances, or control its grain growth. Classic examples are thorium in a tungsten filament, and vanadium in steel; a recent discovery is the similar action of aluminum in carburized metal.

While it is now doubtful whether nitrogen (or chromium nitride) has any pronounced effect on the recrystallization of cold worked ferrite, or embrittlement of chromium-irons after long service at moderate temperatures, it is at least one long step in advance to know that it has a profound effect on the primary crystallization of the melt. A fine-grained ingot is a better starting place than a coarse-grained one!

use metal « use metal » use metal

By F. H. Norton and J. A. Fellows
Massachusetts Institute of Technology

A NEW DEVICE FOR CREEP TESTING

IN ORDER to determine creep values of steel at low rates of flow with more precision than has been possible with apparatus used for some years at Massachusetts Institute of Technology, a new type of furnace has been constructed which promises to give excellent results. A description of this equipment (which was designed for the work done under a fellowship maintained by the Babcock & Wilcox Co.) will probably be of interest to others engaged in this type of work. The temperature controller to be described is not new in creep testing, as it has been employed in England for several years, but an advance has been made both in precision of control and simplicity.

This furnace has been constructed to conform with the recent method of test for long-time (creep) tension tests of metallic materials at high temperature, adopted as tentative standard this spring by the American Society for Testing Materials. Equipment has been made for specimens with a 2-in. gage length (Class II of the A.S.T.M. test) and for specimens with a 10-in. gage length (Class I). The 10-in. furnace will be described.

As shown in the cross-sectional diagram on the next page, it consists essentially of a heavy tube of austenitic steel, *B*. This is material which will not scale after long time at heat and it has no transformations to disturb the temperature-length ratio. It is wound with mica tape and on top this tape is wound a heating coil of "chromel" wire. The coil is divided into three sections, the two closely wound end coils and a center coil less closely wound. The end coils are concentrated in order to compensate for the heat flowing out through the specimen.

The test specimen is a uniform rod 0.505 in. diameter, extending clear out of the furnace where it can be threaded into holders. If the material to be tested is expensive or rare, carbon steel ends can be welded onto it just outside the gage lengths. Welded on the specimen at gage points are two short lengths of platinum wire *F*. Each has a fine scratch on the surface made with a razor blade. These marks, when illuminated by small incandescent lamps through inclined openings, give a fine and brilliant image on which the cross-hairs of the telescopes can be sighted. The sighting tubes *H* are made of steel sheet and closed with a glass cover so that no air currents will disturb the readings.

The whole furnace is insulated with a piece of high temperature pipe covering.

Temperature is controlled automatically by the movement of the furnace tube in the follow-

ing manner: When the temperature rises tube *B* expands, and since the bottom is fixed, the casting *L* on the upper end lifts up the forked lever *M* through steel strips *N* hung from projecting ears on casting *L*. The fixed end of this lever *M* is held by strip *O* to another yoke *R*; it in turn is tied down to platform *P* which is connected to the base of the furnace with three invar rods *Q*.

Any change in temperature is, therefore, at once registered by the contacts *X* at the end of lever *M*. This alters the heating current and at once corrects the temperature. The magnification of the motion is about 10 to 1 so that ample sensitivity is available for a close control. Rapid adjustment is provided at the fixed end of the lever *O* by means of a set screw in the movable casting *R* which compensates for the initial expansion of the furnace on heating. The invar rods reduce the influence of room temperature on the control.

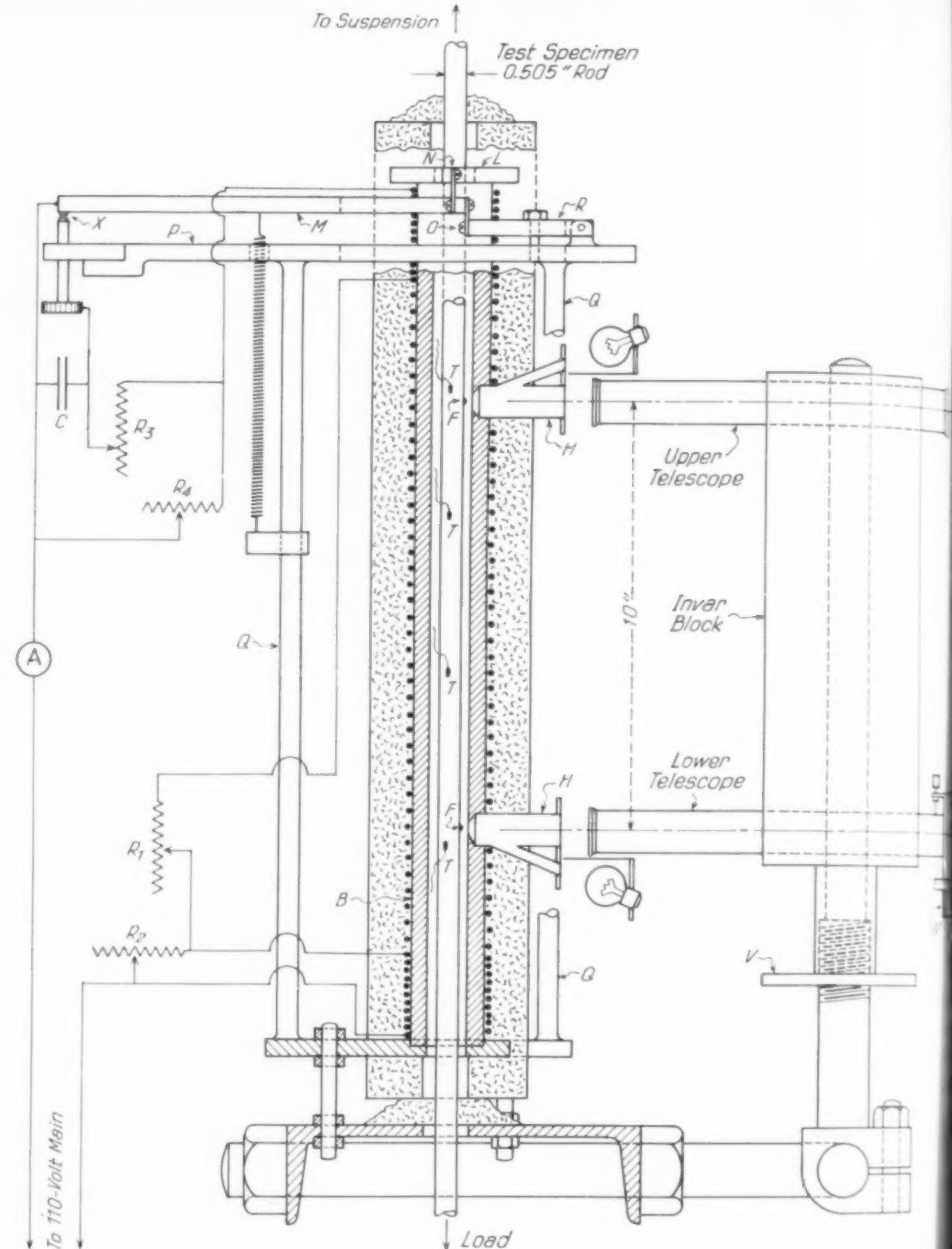


Diagram of Devices for Regulating Temperature and Measuring Extension

The upper telescope has a fixed horizontal cross-hair which, to make a measurement, is set on the upper gage mark by means of the leveling screw and nut *V*. (The lower telescope is rigidly connected to the upper one by an invar block.) The cross-hair in the lower telescope is then set on the lower gage mark on the specimen, using micrometer screw *W*, and the reading taken there.

This method of reading extensions does not give as great a *sensitivity* as many of the mirror extensometers, but it is believed to have fully as much *precision*, for all of the measuring apparatus is outside the furnace at a relatively uniform temperature.

At the left side of the drawing is a wiring diagram for the control of the heating current. The three sections of heating coils wound around the furnace tube are in series. Variable resistance R_1 and R_2 are in parallel with the main coil and one end coil, respectively, to give individual adjustment of the current going through each of these sections. The total current passing through the furnace is regulated by a resistance R_4, in series with the entire furnace.

Actual control of the temperature is accomplished by cutting in and out resistance R_3, which is a comparatively high resistance in parallel with the main resistance R_4. Closing

the contact increases the current through the furnace by approximately 10%. Condenser C (one microfarad capacity) is shunted across the contact points to prevent sparking.

Ammeter A in series with the furnace is very helpful in setting the rheostat R_4 to give a definite temperature. The fine adjustment of temperature is accomplished by turning the contact screw; one-tenth of a turn corresponds to approximately 1° F. in our furnaces.

Measurement of Length

The specimen used in this furnace has a gage length of 10 in., of which the variation in length can be read with the telescopes of 100X magnification to plus or minus 0.00004 in. This corresponds to plus or minus 0.0004% or 4 parts in a million.

The temperature of the specimen, which is read by means of a precision potentiometer and thermocouples T of fine wire ("chromel" and "alumel") welded onto the specimen, can be kept constant to within plus or minus 0.5° F. by the automatic control. This temperature regulation is better than needed for the precision of the telescope and mounting, as 0.5° corresponds to a change of about one part per million in length.

Temperature is generally read in three places along the specimen to insure uniformity. Typical temperature distribution along the specimen in this furnace is indicated by the following observations:

Temperature at top gage point	895° F.
Temperature 3 in. below	897° F.
Temperature 7 in. below	897° F.
Temperature at bottom gage point	898° F.

With this type of controller the temperature of the specimen is affected to some extent by changes in room temperature, because even though the furnace tube itself is held rigorously constant in length, variation in room temperature will run the temperature of the specimen up or down a few tenths of a degree by variations in the amount of radiation from the ends of the specimen. For precision work room temperature should be constant (to ± 2° F.).

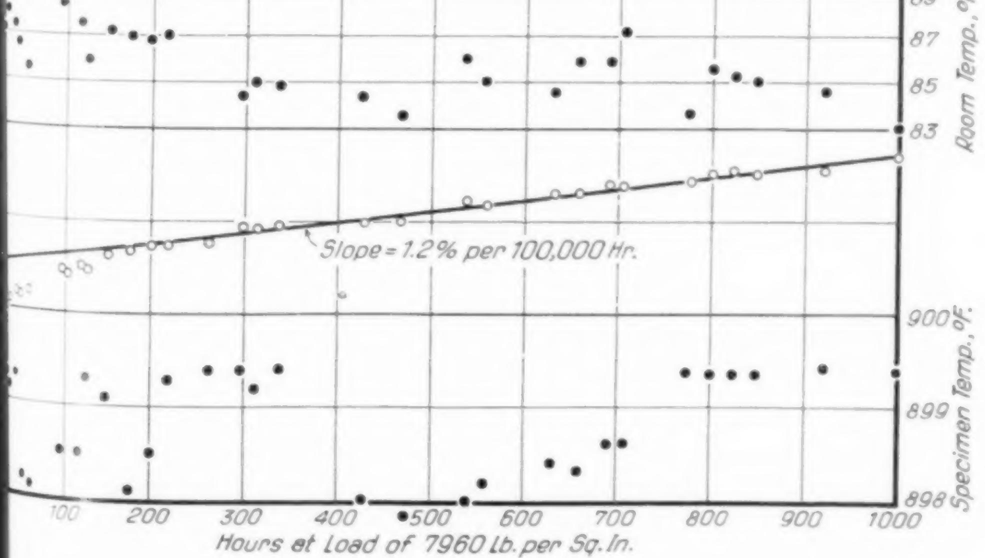
While we can usually maintain our room temperature within this interval with an automatic controller, there are occasions due to sudden changes of outside temperature or shutting off of furnaces, when we get considerably greater variation. Most of the irregularities in length readings can be traced to this.

Presented herewith as a sample of the work done by these machines is the result of a run on a bar of cold rolled steel, loaded to give a creep rate of approximately 1% in 100,000 hr. at 900° F. The analysis of the steel was carbon 0.12%, manganese 0.81%, silicon 0.06%, sulphur 0.166%, and phosphorus 0.111%.

It will be noted that the slope of the line drawn through the observed points is determined with sufficient precision, even at this comparatively low rate of creep, to allow us to state definitely the flow rate to the nearest tenth of a per cent in 100,000 hours.

On the basis of this preliminary run, a number of creep furnaces of this design are being constructed. It is believed that with a more constant room temperature the furnace will hold to within plus or minus 0.2° F. over long periods of time, as it does now over frequent periods, several hours in duration.

Specimen Curve Sheet for a Creep Test



By R. J. Cowan, Surface Combustion Corp., Toledo, Ohio

Recent Progress in Carburizing with Gas

THE first commercial installation of the so-called eutectrol process for continuous gas carburizing was placed in operation the latter part of December, 1931, at the plant of the Chrysler Motor Corporation, Newcastle, Ind. This unit was described in METAL PROGRESS, February, 1932. It has been in continuous service up until the latter part of June this year at which time it was decided to lengthen the furnace so as to obtain greater production. Examination of the old muffle showed that it would be advisable to replace it in order to avoid a shut down at a later date.

In the 18 months of service, there have been but two or three times when it became necessary to shut down for a few hours to make minor repairs. Since this furnace has been in operation so long, and other furnaces of the same kind have been installed to carburize other classes of work, a number of interesting observations may be recorded for the advancement of the art.

In the original description of this process, attention was directed to the fact that carburization is carried on in three successive steps. In the first, which corresponds to the heating zone of the furnace, the work becomes covered by carbon from the catalytic breakdown of hydrocarbon gas. The second step is characterized by the fact that at carburizing temperature, the carbon so deposited reacts with an oxidizing agent, supplied in the form of flue gas. The third step consists of diffusing the carbide (in the presence of a hydrocarbon gas) to the desired case depth. In the development that has taken place during these months of operation, it has been abundantly proven that these fundamental conceptions are right and that when they follow each other in logical sequence, dependable and satisfactory case hardened surfaces are obtained.

In the installation at Newcastle natural gas was used as the carburizing medium. Along with this natural gas was mixed a certain proportion of flue gas, specially prepared by washing and drying. It required a few days' operation to determine the correct proportions of these gases to produce the desired results, after which the gages which control the flows were set to deliver the required amount. It is an interesting fact that throughout the months this furnace has been operating, the original gas setting has been maintained. This is not to say that other mixtures have not been tried, for changes have been made from time to time to observe the results obtained, but in no instance were better results obtained. It has been found that the flue gas need not be completely dried.

but that a certain amount of moisture, so long as it is a uniform amount, has no injurious effects upon the process.

A second furnace at the same plant has been in operation for more than a year and the results obtained have been quite in harmony with those obtained on the first furnace. In this instance, the steel used was a 3½% nickel-molybdenum steel requiring a case depth of 0.075 in., instead of the S.A.E. 1020 steel with a case depth of 0.040 in., as required on the first furnace. This second furnace was operated at a higher temperature and the results have been very gratifying, particularly as to uniformity of case and freedom from distortion.

The first upset that occurred in the operation of these furnaces came at a time when a lot of new trays was placed in service. A number of these trays were in the furnace when it was observed that the case depth had dropped from the usual 0.040 in. to about 0.010 in. although everything about the furnace seemed to be functioning properly.

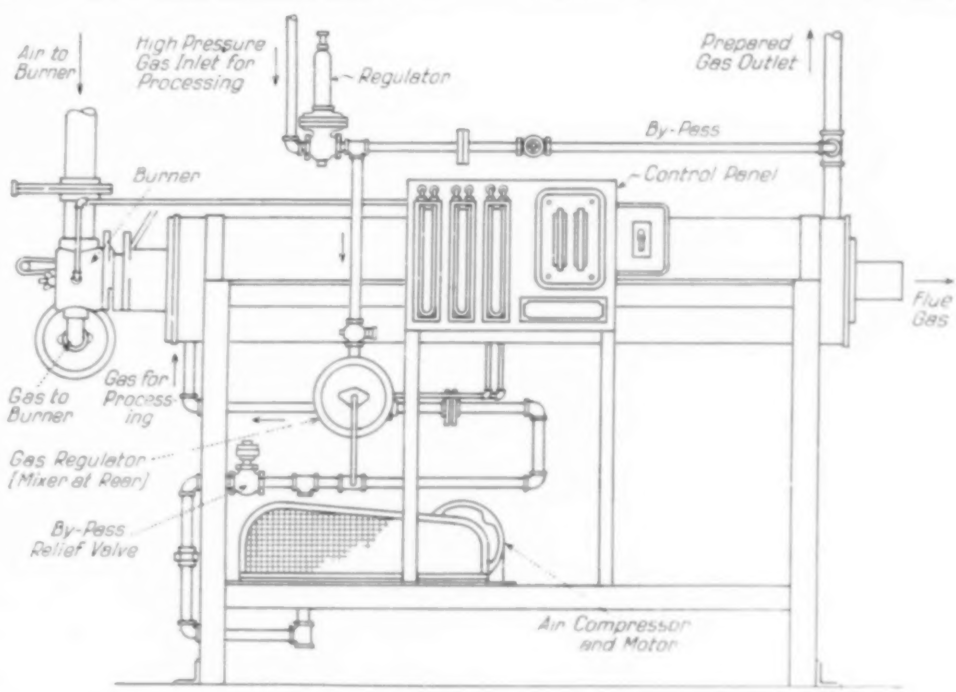
The new trays consisted of an alloy usually referred to as "35-15," containing approximately 35% nickel and 15% chromium. It was found that such an alloy affected the carburizing reactions in a harmful way, and trays could not be used until they had been thoroughly carburized. After having gone singly through the furnace a number of times, they then became "conditioned" and did not affect the reactions in an injurious manner.

It was found that if new trays of this composition were copper plated, the effect upon the carburizing reactions would be very much retarded. As the copper plating wore off progressively, the tray became progressively "conditioned."

In order to investigate this matter of proper composition for trays and carriers, several leading alloy manufacturers submitted trays for trial purposes. A tray submitted by the Michigan Steel Castings Company, known as "28-8" (28% chromium and 8% nickel), was found to be very satisfactory. Trays of this and similar compositions could be used in the furnace without any previous conditioning and give satisfactory results.

The staff of the Chrysler Motor Corp. are entitled to a great deal of credit for their patience and persistence in solving this problem. Particularly A. E. Thomas, plant metallurgist, made many valuable contributions along these and other lines.

When the muffle was removed from the first furnace recently, it became possible to examine the metal sections and note what the effects had been upon them after having been at temperature 18 months in a carburizing atmosphere. It is interesting to note the results obtained by the analysis of borings taken from the inside of each of the six sections. Carbon contents were as follows: Section 1 — the charge end — 0.25%; section 2, 1.60%; section 3, 2.26%;



General Drawing of Device for Cracking Heavy Hydrocarbons Before Use in a Gas Carburizer. Capacity 100 cu. ft. of prepared gas per hr.

Structure of Muffle Wall (Chrome-Iron) in Hot Section After 18 Months Service. Inner portion is highly carburized and very large crystals have grown. Magnified about 3 times. This view and micros by F. D. Widner

section 4, 2.50%; section 5, 2.55%; and section 6 — the discharge end — 2.60% carbon.

While these high carbon analyses at the inner wall may occasion no surprise, there had been considerable carbon migration throughout the entire thickness. The same section that gave 2.50% carbon on the inside of the muffle gave 1.09% carbon on the outside exactly opposite. Typical microstructure is shown at the right on the page opposite.

It will be remembered that the two first sections of this muffle were made of chrome-iron containing 25% chromium with only about 0.20% nickel. One of these sections was at the cold end, but the other extended into the carburizing zone and was at carburizing temperature. An examination of this section, which had been at high temperature, revealed a very interesting fracture, and a macrograph is given at the top of the page. A micrograph is given also showing a similar section of this metal (left of page 47). As remarked when discussing trays and carriers, considerable information has been gathered on the way different heat resisting alloys act in a carburizing atmosphere.

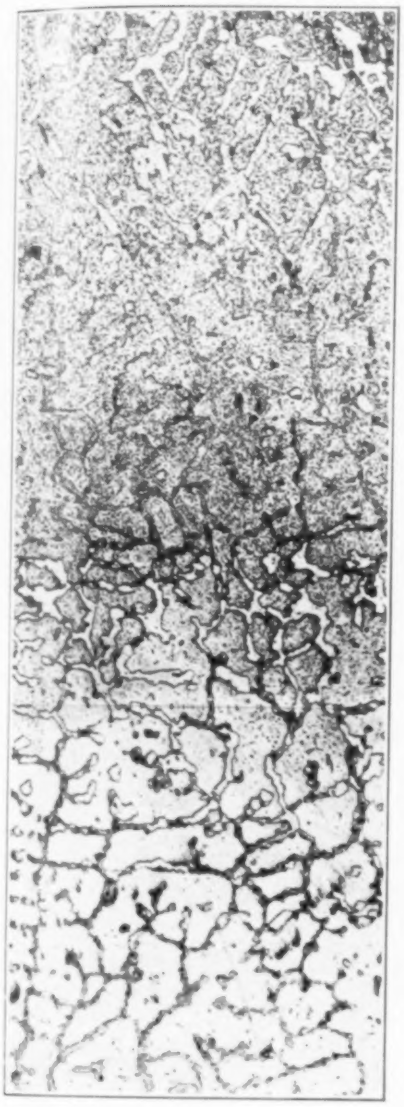
An exact duplicate of the first furnace built was installed in the plant of the Timken-Detroit Axle Co. There was this fundamental operating difference, however — that instead of using natural gas as the carburizing medium, propane gas was used, mixed with a certain proportion of flue gas.

The steel to be carburized was S.A.E. 4615 (nickel-molybdenum) and it was desired to obtain a high carbon case which could be quenched directly from the furnace and produce a file hard surface. When operating in this way (that is to say, using flue gas with propane) it was found that certain characteristics of the propane had to be taken into account and this brought about conditions very difficult to control.

When propane or butane are heated, they do not break down directly with the liberation of carbon and hydrogen but form a number of intermediate products, among which are some resinous substances which, upon further heating, form coke. This coke forms upon the surface of the work which is to be carburized and interferes with penetration and hardening. The result is that underneath this coke there will be a shallow case and insufficient hardness on quenching. For this reason, the presence of this coke causes spotty carburization.

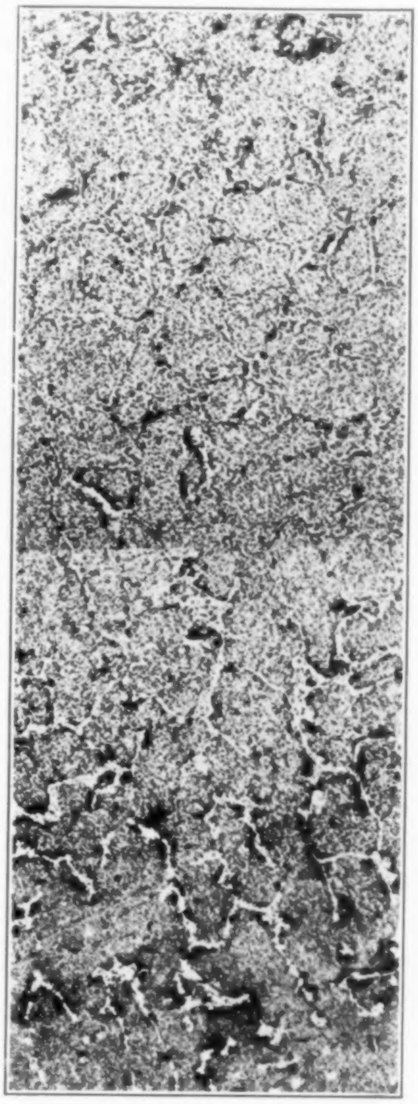
When an attempt is made to produce a higher carbon case by adding more propane or butane, there will be produced at the same time a correspondingly larger amount of this coke which will aggravate the very condition it is intended to correct. It should be said also that the temperature from which the steel is quenched has been found to have considerable effect upon the surface hardness produced. However, the main problem resolved itself into one of finding out how to prevent or retard the breakdown of the hydrocarbon.

It is a common observation in physical chemistry that when it is desired to prevent or



Structure of a Chrome-Iron Muffle Showing Carburized Edge. Etched with Murakami's reagent. 100 ×

Carburized Surface of 35-15 Muffle After Staying in Carburizer for Many Months. Magnified 100 diameters



butane that is to be used. When properly proportioned, these will pass through the different steps of the "eutectrol process" as originally outlined and produce a satisfactory high carbon case on the steel.

A convenient source of hydrogen is found in manufactured city gas, which also contains a large percentage of carbon monoxide and a little carbon dioxide. Since these gases in themselves are oxidizing gases, it becomes unnecessary to add more oxidizing gases to the propane in the form of flue gas, for, in addition to the amount of oxygen introduced into the reaction chamber in this way, a certain amount of air gets in each time the charging door is opened for a push. Therefore, flue gas is not used with propane, except when it is desired to purge the furnace antechamber.

It was realized that in order to function properly in this way, it would be necessary to have a constant supply of uniform city gas or its equivalent. It is well known that this gas is sold on the basis of its B.t.u. value which is held constant although its chemical composition may vary from time to time, and from place to place.

The first attempt to produce a gas of uniform composition that could be used for diluting propane, and which was better adapted to the purpose than city gas, consisted of breaking down methanol. By this means both hydrogen and carbon monoxide were produced in quantity, but it was felt that the cost would probably be too great. After further research, it was found that different mixtures of propane or butane with air and flue gas would produce the desired reaction products when passed through a heated tube in the presence of suitable catalysts. The results obtained by this means are very gratifying and a number of exhaustive tests have given excellent results.

In a recent run S.A.E. 4615 steel was carburized by the so-called "cracked gas" mixed

retard the breakdown of a hot gaseous substance, it may be heated in the presence of some of the elements that would normally be formed by the breakdown. In the present instance, carbon and hydrogen are the elements ultimately formed from propane. If this thermal breakdown be conducted in an atmosphere containing considerable hydrogen, the action will be retarded.

This is the principle that was finally used to overcome these objectionable characteristics of the higher hydrocarbons. An atmosphere rich in hydrogen is mixed with the propane or

with butane. Three successive 8-hr. runs gave very uniform results. Quoting the metallurgist who supervised the test: "Our results show that the total depth of case varied over-all not more than 0.008 in., the actual range being 0.064 in. to 0.072 in., which we would consider very satisfactory, well within our limits. This is particularly pleasing in view of the fact that a total number of 240 readings were taken to make this determination."

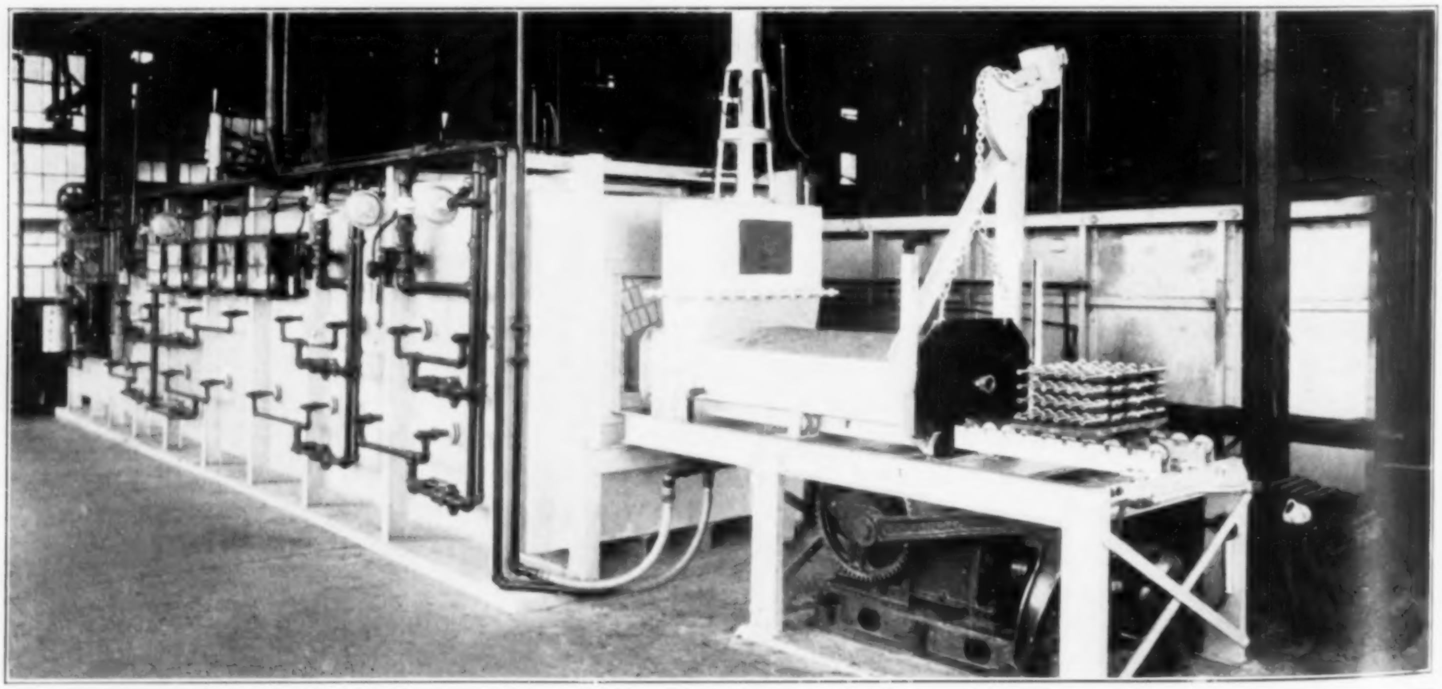
There has been designed and built a self-contained unit for producing this cracked gas, and this will be used in all cases where the higher hydrocarbon gases are used for carburizing. A general drawing is shown on page 45.

Acknowledgment must be made of the fine contributions of H. W. McQuaid of the Timken-Detroit Axle company and of R. E. Haislip of Chrysler's Detroit plant. They have both given considerable time and study to this matter and it is impossible to record in detail the many interesting and valuable observations they have made in an attempt to determine the limitations of the process.

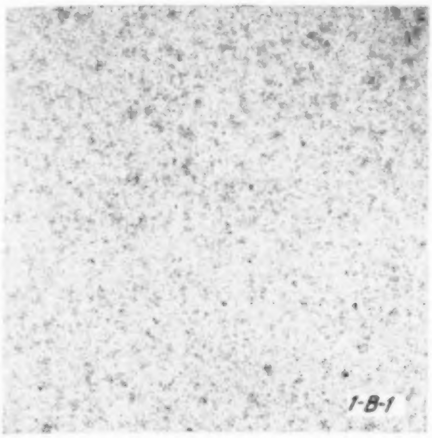
Mr. McQuaid has experimented with a specially formed oil gas. He has also used an intermittent gas flow; for certain periods the gas flow was discontinued, and followed by other cycles of flow or soaking so regulated as to obtain the specific results. In each instance, satisfactory effects have been obtained. Another method used at present is that of mixing propane with city gas and introducing them into the muffle at the discharge end of the furnace rather than at the charge end as originally planned. By this means, the furnace chamber itself becomes a cracking unit, to deliver into the first or heating zone a hydrocarbon gas of such character as will avoid the objectionable deposition of coke described above. This method of operating is giving satisfactory results and is subject only to the variables occurring in the rather large volumes of city gas that are being used.

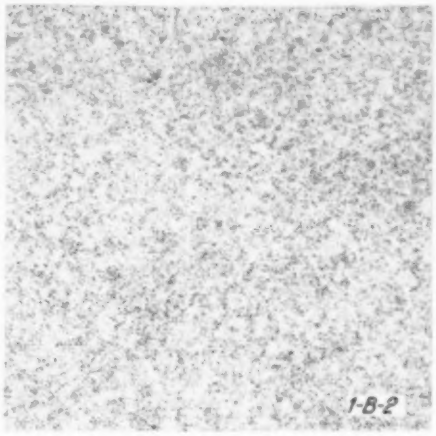
Mr. Haislip conducts the operation in a little different way. He prepares, in the flue gas unit that is supplied with these furnaces, a special flue gas of a highly reducing character — that is to say, high in CO and low in CO_2. This is mixed with city gas and then proportioned with the desired amount of butane. It is producing very satisfactory results in the carburization of camshafts. A view of his furnace is printed on this page.

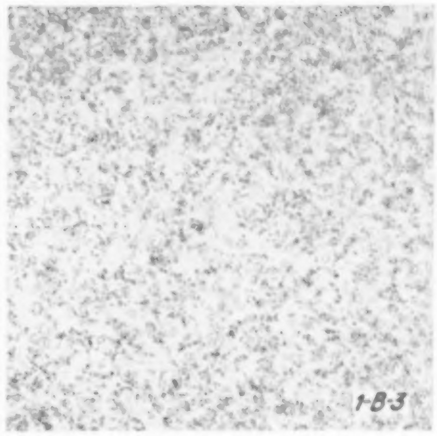
Continuous Gas Carburizer Used for Carburizing Camshafts



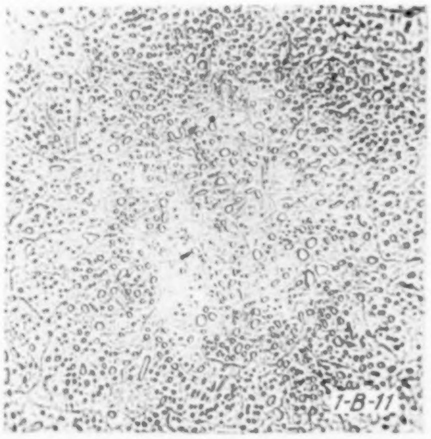
Cementite-Free Boundaries in Quenched 1% Carbon Steel

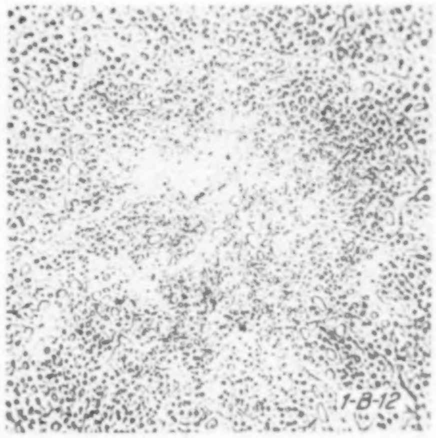


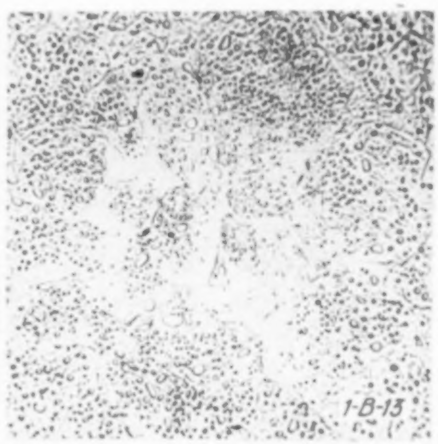


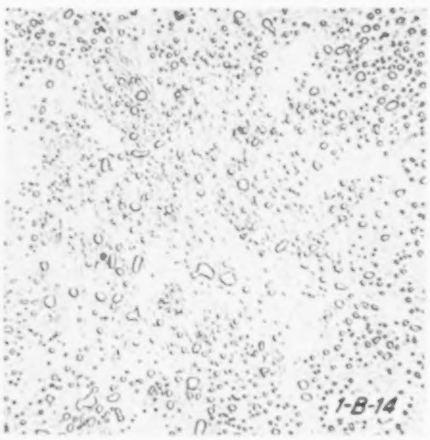


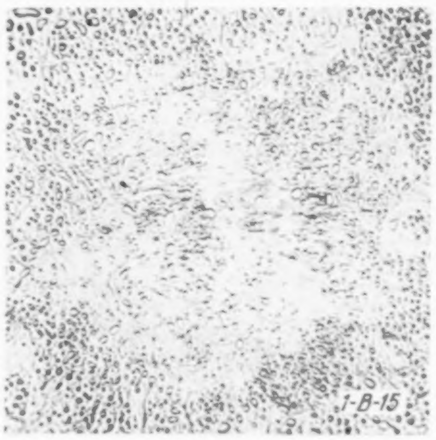
1-B-1, 1-B-2 and 1-B-3 at 100 diameters

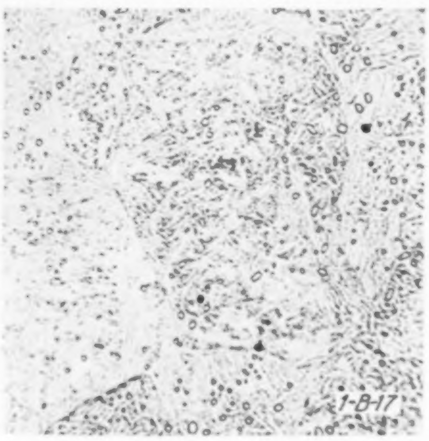












1-B-11 to 1-B-17 inclusive at 1000 diameters
All Etched with 1% nital

CEMENTITE-FREE boundaries occur in increasing degree and prominence, giving the structures illustrated on this sheet, with higher hardening temperatures and longer soaking times

Photomicrographs by SKF Research Laboratory

When ALCOA Aluminum Rides the Rails

Prophecy fulfilled in three short years! Advertisement below appeared in the Saturday Evening Post, June 21, 1930.

there is Safety, Speed and Saving

"Help us re-design—help us give better service more economically," the railroads are asking the equip- ment companies. And the latter are answering with radically *new* trains—stream-lined trains, motor- powered trains, *trains made of the light, strong alloys of Alcoa Aluminum.* Using this metal, tons of need- less dead-weight are eliminated, yet structural parts are actually thicker, sturdier, *safer.* With dead weight cut, speed is increased; starts, stops, accel- eration are smoother; power and maintenance costs are greatly reduced. What Alcoa Aluminum brings to trains, it brings also to buses, truck bodies, ele- vators, tank cars—every unit of transportation.

The modern trend in rolling stock—Union Pacific's Rail-Plane—a new high speed, light weight, stream-lined train, made of Alcoa Aluminum alloys. Everything's smooth—not a break in contour from stem to stern. Its three-car unit carries the engine, railway postoffice, baggage car, buffet diner, and 116 passengers—the equivalent of an ordinary passenger locomotive and train. Yet altogether this train weighs even less than a standard single Pullman car. Powered with a 12-cylinder automotive engine, 600 horsepower carries this train as fast as 110 miles per hour—contrasted with 2000 to 4000 horsepower needed to haul ordinary fast trains. Faster, safer, more comfortable, *it actually costs less per passenger mile to operate than a motor bus!*

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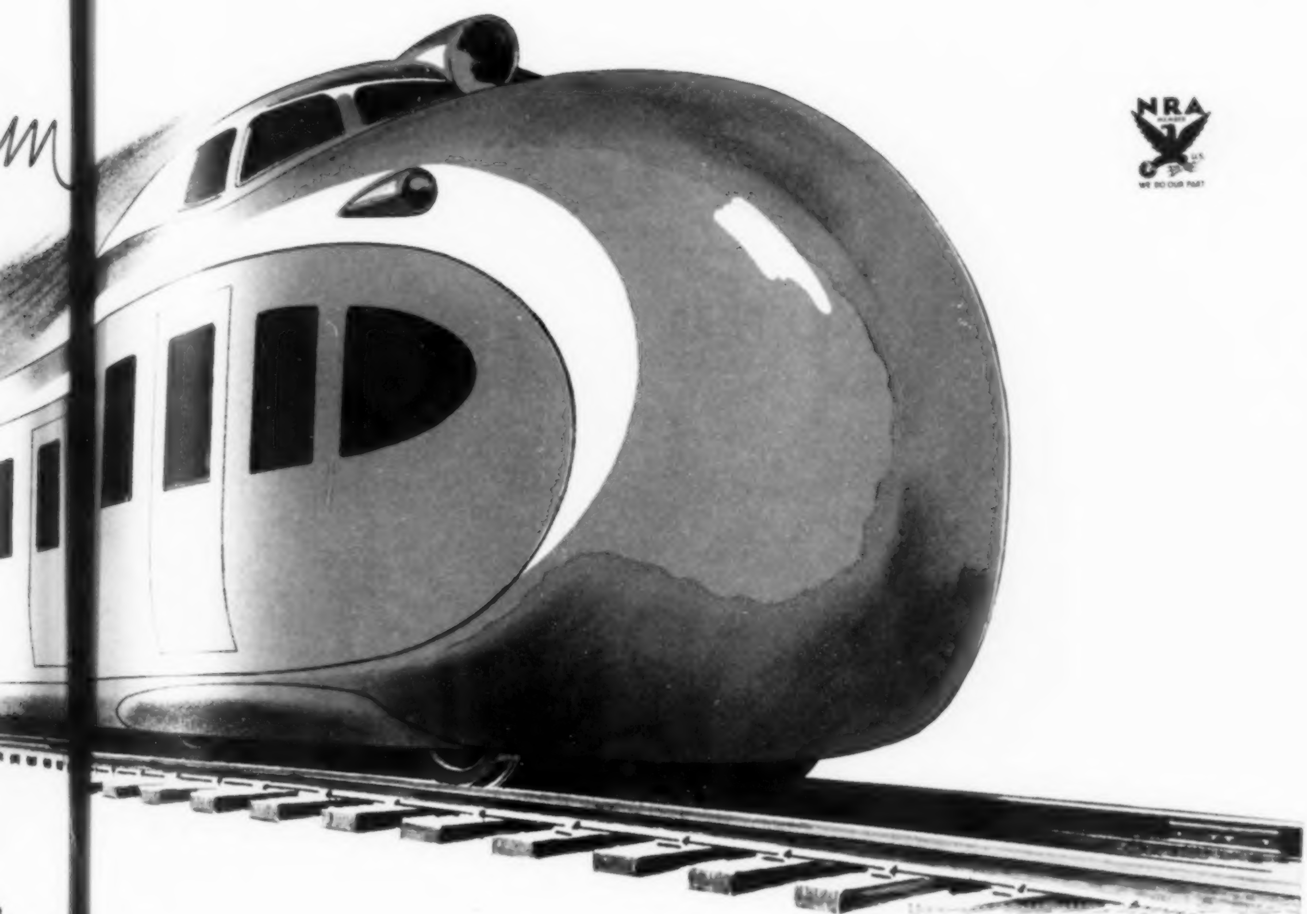
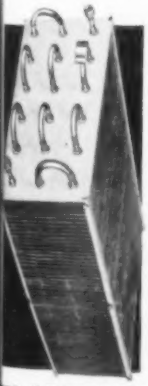


Every industry profits from Alcoa Aluminum

In every industry, the men who set the pace are investigating the possibilities of Alcoa Aluminum. Strong as structural steel, yet only 1/3 as heavy, the alloys of this modern metal are lifting dead-weight from production equipment, increasing efficiency. They're non-contaminating, non-magnetic, high in heat and electrical conductivity. They bring light weight, durability, attractiveness to the finished product. In the factory, paint made with genuine Alcoa Albron powder as a pigment will brighten interiors, protect surfaces from rust, weathering, smoke and acid fumes.

Alcoa Aluminum can make *your* production more efficient, *your* product more saleable. Let us show you how. Also how to use, form and handle this metal. Address: ALUMINUM COMPANY *of* AMERICA; 1801 Gulf Building, PITTSBURGH, PA.



EP COOL WITH
COA ALUMINUM

Aluminum, used for fins, and fittings in these re- coils, dissipates heat because of its high thermal ... Easier to install, ... of its light weight. ... food refrigeration be- ... isn't affected by com- ... refrigerants.

THAT FINISHING TOUCH

Thanks to Alumilite, the new protective finish for aluminum, your product can have a permanent, attractive, sales-stimulating color. Color becomes an integral part of the metal—it can't crack or flake, even when the colored product is stamped from a coil! Process owned by Aluminum Colors, Inc.

NO FEAT AT ALL

This man is lifting an Alcoa Aluminum casement window taller than he is and three times as wide. Because of its light weight it can be easily handled, easily installed. No warping. No splitting. No maintenance. No drip-staining of adjoining surfaces.

ALUMINUM

CORRESPONDENCE

Improved Open-Hearth Furnace

TURIN, ITALY — In one of my early letters to METAL PROGRESS (March, 1931) I took the opportunity of quoting the results obtained with an open-hearth furnace of a new design by F. Fiorelli and perfected at the Terni steel works. As pointed out at that time, fuel economy was a matter of special interest to the Italian steel industry, on account of the somewhat higher cost of coal in our markets as compared with that in other countries.

The characteristic features of the new furnace consist of two uptake flues through which air is blown by fans, a chamber where air and gas are completely mixed before entering the hearth, and the special arrangement of air and gas ports by which the velocity of the flame, its inclination and the conditions of combustion can be easily regulated to suit the requirements of the different periods of the melting and refining processes.

By this means it is possible to burn the gas rapidly to develop a very hot flame while melting the cold charge, and later to burn it more gradually with a highly luminous flame, as is indispensable for heat transfer during the decarburizing and refining period. This results in a great increase in production and decrease in furnace repairs and fuel bills — results which have caused steel makers in various European countries to adopt this new furnace in very remarkable numbers. This has proved that fuel economy is now considered to be a very important contribution to the problem of lowering production costs, even in many coal producing countries.

In addition to the 10 furnaces at the Terni steel works, four furnaces have been built at the Voltri steel works and 15 furnaces by the Ilva company.

In Poland the Huta Bankova Co. has purchased from the Terni company the patent rights for 72 open-hearth furnaces, of which five are now in operation.

In France, Schneider and Co. of Le Creusot has now five of them in operation. Forges d'Audincourt has two and Chatillon Commentry

Performance Before and After Remodeling

	Furnace No. 1		Furnace No. 2		Furnace No. 3	
	Before	After	Before	After	Before	After
Total output, tons	1586	2153	1283	1834	1581	2254
Average heat, tons	34	42.5	25.5	32.5	33.8	45.7
Time per heat, including repairs, hours	6.03	5.45	5.39	5.02	6.08	5.27
Coal consumption, per cent of steel	24.9	18.4	21.1	16.9	23.1	17.9
Increase of output	34%		44%		49%	
Fuel economy	25%		19%		22.7%	

seven. In England 21 furnaces have been remodeled recently according to this system.

In the last two years many further improvements in the design have increased the fuel economy obtained in the first furnaces built in Italy. The table on page 52 contains a few figures showing the results obtained with three furnaces before and after remodeling, based on a campaign of two weeks.

The peculiar advantages of the new furnace design are not confined to the manufacture of ordinary commercial steels, as can be seen by the following table, showing average results obtained at the Terni steel works in a year's run,

Yearly Performance of Open Hearths

Lining	Acid and Basic		Basic	
Nominal Tonnage	20 to 25 Tons		40 to 45 Tons	
Quality Produced	Special Steels for Railways Materials and Ordnance		Cr-Ni Steels for Armor Plate and Various Forgings	
	Before Remodeling	After Remodeling	Before Remodeling	After Remodeling
Charge, tons	18 to 22	18 to 22	42 to 46	44 to 48
Average heat, tons	9	20	18	42
Daily output, tons	55	70	115	150
Time per heat, including repairs, hours	8	6.10	8	6.30
Coal consumption, per cent of ingots	28	23	27	21
Increase of output	27%		30%	
Fuel economy	18%		22%	

making high quality and special steels with the new furnaces, as compared with the results obtained under identical conditions in the previous year before the furnaces were remodeled.

Experience has abundantly shown that any conventional open-hearth furnace can be easily remodeled to the new design at a cost not exceeding the amount of the repairs normally required after a long run. This is one fact explaining the speed with which the furnace has been accepted by European steel makers.

FEDERICO GIOLITTI

Blistering of Aluminum

SCHWEINFURT, GERMANY — The April issue of *Zeitschrift für Metallkunde* contained a very interesting report by Messrs. Brenner, Sauerwald, and Gratzek of their investigations at the Aircraft Research Institute, and the Department of Metallurgy, Breslau Technischen Hochschule, on the formation of blisters during heat treatment of hardenable aluminum alloys. Thirteen materials were studied, of which most work was done on a pair of 4.10% copper alloys containing about 0.60% magnesium, 0.30% silicon, 0.40% manganese, and 0.30% iron.

The trouble is deep seated, rather than a superficial flaking; if a blistered sheet is sectioned through two or more of the defects, it will be found that an egg-like cavity exists near the center of the sheet, bulging both surfaces outward in a rounded bump.

A nitrate bath blistered pieces very badly, both in the condition as delivered and after the surfaces had been sandpapered. Annealing in air or in steam gave the same results, although not quite so bad. Sheets as received and after sanding did not blister in argon, even at 1100° F., nor in a vacuum. Hydrogen, purified of oxygen by passing over hot copper, blistered both sheets, on the whole, quite badly. Nitrogen containing a little oxygen did the same to sandpapered sheets, but those with a mill finish came out smooth.

Compound treatments were also tried. First a vacuum anneal was given. A second 3-hr. anneal in a nitrate bath or in a nitrogen atmosphere caused no blisters. Re-annealing in purified hydrogen had no effect on sheets as delivered, but blistered sandpapered samples.

As to the relationship between temperature and time, it was found that the material blisters most rapidly at higher temperatures; for example, if a susceptible alloy is annealed at 1025° F., blisters will appear within 10 sec., while if it is annealed in a salt bath at 925° F., it will take much longer.

Besides the influence held by the surface the influence of cold work was studied. Sheets stretched 8% and more developed no more blisters than formerly. The same results were obtained with cold rolled sheets.

The alloy shows the eutectic structure, in accordance with the high annealing temperature. Blisters seem to occur most readily in those places where the eutectic is formed; nevertheless, blisters can form at temperatures somewhat too low for the eutectic to appear.

The authors of the above-mentioned paper

are not able to give a definite and completely satisfactory interpretation of all their experimental results. They note the following factors as being of most importance:

1. Blisters will not form without the assistance of the surrounding medium.

2. Some substance exists in the alloy which causes their formation.

Sheets annealed in argon and in vacuum show no blisters; neither will sheets annealed in a salt bath if they have first been annealed in a high vacuum. From this it can be concluded that sheets containing no gases can produce no blisters.

It is well known that more or less hydrogen is dissolved by hot aluminum alloys. Silicon, nitrogen, and phosphorus already there presumably form hydrogen compounds of larger volume, especially in the type of metallic alloy concerned here. These gaseous compounds, formed with sufficient speed, cause internal ruptures within the sheet. The speed of gas formation is the deciding factor. Slowly evolved gases, which diffuse without developing sufficient gas pressure do no damage.

That the annealing atmosphere is of critical importance is shown by the fact that when the outer oxide layer is disturbed by sandpapering the surface, gases penetrated into the alloy more easily and the formation of blisters was thereby promoted. Hydrogen and constituents forming hydrogen compounds can therefore be regarded as the main cause of the blisters. Hydrogen alone will not, since its high rate of diffusion will not permit the development of sufficient pressure.

HANS DIERGARTEN

correspondence

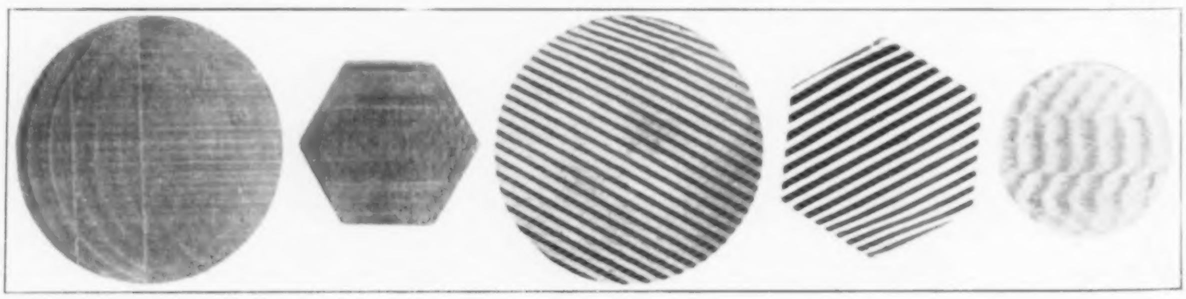
Figures on Sawed Surfaces

SENDAI, JAPAN — Two kinds of figures are usually observable on the section of a metallic rod sawed by a hacksaw. The first is in slight relief, and the markings are more or less parallel to the periphery of the section. This class is shown in the first two views of the adjoining strip. The second is deeply in relief, and the streaks are independent of the periphery of the section. (See No. 3 and 4 of the strip.) Tôru Hosaka and Ichiji Moriya, after a study, have concluded that these figures are caused by forced oscillations of the sawblade rather than any inherent structure in the metal.

It is well known that the sawteeth generally are set alternately to the right and left. When the teeth of a blade are straightened out and a cut made on any of the above illustrated bars, no figures are developed on the sawed section. Experiments also proved that the greater the teeth deflection sideways, the higher the relief; hence the depth or relief of the streaks depends on the set of the teeth.

Experiments also show that the distance center to center of the streaks is always the same as the pitch of the sawteeth. An important fact regarding the figures above mentioned is that the peak of a ridge always appears on the periphery of the section.

On brass, iron and steels, the figures are



Figures Appearing on Sawed Bars; Saw Travels in Horizontal Direction

correspondence

conspicuous, while they are seldom observed on softer metals, such as copper or lead.

To develop a reasonable explanation of the mechanism whereby these figures in relief are built up, consider the two line drawings. in sawing, the blade moves under pressure and cuts the material in the direction of the arrows. Teeth that have not reached the specimen are in a free state as compared with the teeth working on the specimen. The latter are acted on by a side thrust from the sides of the cut (kerf) toward the right or the left; consequently the sawblade will be deflected to the right or left side. As sawing proceeds, each tooth bites more deeply into the material toward the right or the left side, and when it reaches a certain limit, the blade separates from that side by an elastic force and is shifted to another side, and so on, repeating the very motion. Thus the blade is forced to oscillate laterally during its stroke.

Consider a pair of teeth within the specimen; they are acted on by forces which constitute a couple. Consequently the kerf is widened to some extent. At the edge of the specimen, on the other hand, only one of the forces of the couple is acting, and a narrower kerf is cut. This explains why a figure similar to a node is observed on the edge of the left two specimens illustrated.

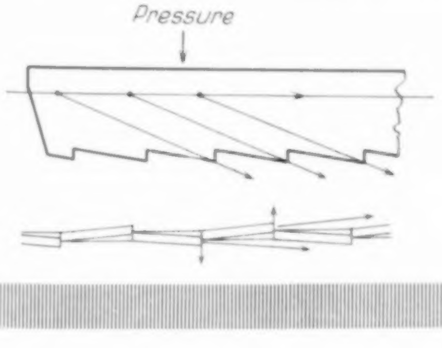
Next consider the second kind of pattern. It is confirmed by experiment that these figures streaked with inclined lines are obtained when the sawblade has a specially large deflection at the teeth. The form of these streaks is unaffected by the periphery of the section, and by diminishing the teeth deflection, the figures disappear.

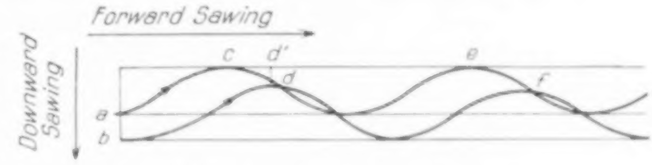
The interval between the streaks in these figures, measured along the line of strokes of the saw, is always equivalent to twice the pitch of the teeth. It may then be concluded that the figures of the second class can be produced by the same mechanism as the first — that is, by forced oscillation of the sawblade. In the present case, however, the saw has a larger deflection, bites deeper into the sides of the specimen, and consequently the characteristic figure is conspicuously rugged.

Owing to the vertical oscillation of the blade, the bottom of the kerf also has low relief. Curve *a* of the diagram shows the ideal form. Positions *c* and *e* are the peaks of the streaks which are also produced on both sides of the kerf. In the subsequent stroke, the blade saws down from *a* to *b*, *c* to *d*, and *e* to *f*, the depth being always greater in the peak than in the valley; hence the upper face of the material appears to be cut in the forward and downward directions as shown by curve *b* - *d* - *f*.

For this reason the phase of the wavy trace will advance in the direction of sawing by the amount *c* - *d'* and the same holds good for the streak on the side of the sawcut. The undulations move forward at every stroke in a direction which is the resultant of the downward sawing and the phase advance. These depend on both the pressure and the resistance acting on the blade. If, according to circumstances, one of them varies, or both of them vary at different rates, the inclination of the streaks varies abruptly. This has been frequently observed, as in the last section on the photographic strip.

KOTARO HONDA





Drawing at Left Indicates Forces Acting on a Hacksaw. Drawing at right represents wavy bottom of kerf

correspondence

Ferromanganese and Spiegel From Electric Furnaces

GROSNY, U.S.S.R. — Ferromanganese in two grades (50 to 60% and 80%) and spiegeleisen (12 to 20% manganese) were the only ferro-alloys produced in Russia before the War. All of this came from blast furnaces in the South. In 1923 production had all but ceased, but since then has been on the steady upgrade. For instance, about 20,000 metric tons of 80% ferromanganese was produced in 1913; in 1923 it was 2387 tons, but by 1929 had grown to 43,450 tons. That year 27,800 tons of spiegel was produced.

All of this came from blast furnaces of the "Southern Steel Trust," yet was not sufficient to supply the growing demand, and much was imported from Germany, France, England, and Poland in exchange for high grade manganese ore mined in the Tchiaturi and Nikopol deposits. Since that time a special effort has been made to expand production of essential ferro-alloys, for the Plan calls for a production of 22,000,000 tons of steel in 1937, which will need upwards of 300,000 tons of ferro-alloys.

Since about 85% of this will be consumed in the Ukraine, this (and the Ural district) is naturally the site of the new plants. A point of special interest is that they contain electric furnaces exclusively. Of course, many ferro-alloys are so made, universally, but the common manganese alloys are almost exclusively the product of the blast furnace.

A number of experimental campaigns were conducted with different types of electric furnaces, and the results made it appear that it would be more economical to make the manganese alloys in that way than to appropriate the blast furnaces making much-needed pig iron, or build new blast furnaces for nothing but ferro-alloys. Despite good progress with the new plants, it has not yet been possible to eliminate all blast furnace ferro-alloys.

The most important of the new plants is known as "Dneipro-Alloys." Plans call for 17 furnaces, of which four of the French Miguet-Perron type, each with a capacity of 10,000 kw., were put in operation last year. Power comes from the 800,000 - hp. hydro - electric development on the Dnieper River. Eventually this smelter will produce 80,000 metric tons of 80% ferromanganese yearly (with a possible expansion to 160,000 tons), 20,000 tons of 75% ferrosilicon, 4000 tons of ferrochromium, and 1500 tons of ferrotungsten. Equipment will include nine single-phase furnaces of the Miguet-Perron type, three furnaces of the carbide type, 1600 kw. each, one of 1000 kw. and another of 750 kw., and three furnaces for ferrochrome. Manganese ore will come from the Nikopol deposits having reserves of 75,000,000 tons; iron ore from Krivoy Rog, and chrome ore from the Urals.

Most of our ferrosilicon is now coming from Cheljabinsk in the Urals. It was originally designed to produce 10,000 metric tons of ferrosilicon, 1500 tons of ferrochrome, and 500 tons of ferrotungsten annually. Raw materials come from deposits in the Ural district. Electric power is generated in a steam plant nearby.

Equipment and three-phase furnaces were built and installed by Siemens & Halske of Berlin. These have a capacity of 7800 kva. for ferrosilicon; two of 1300 kva. each are for ferrochrome, and one of the same size for ferrotungsten. Remarkable progress has been achieved in these three-phase furnaces on ferrosilicon.

Energy consumption equals 5300 kw-hr. per ton of 45% ferrosilicon, and 9500 kw-hr. per ton of 75% ferrosilicon, which is thought to be lower than at many foreign works. This has been made possible, in part, by substituting raw coal for a mixture of charcoal and coke as a reducing agent in the charges making 45% ferrosilicon, whereby the saving in power amounts to 10%, the operation of the furnace is improved, and the product meets standard specifications.

A third plant in the Caucasus is under construction, and the first units are already in operation. It will make 80% ferromanganese, and as soon as pressing home demands are satisfied, will have a surplus for export. This will be described in another letter.

Lastly, the new five-year Plan calls for a ferro-alloy plant in Siberia. Work on this site has not yet commenced.

B. M. Suslov

correspondence

Test Pieces for Irregular Castings

LEOBEN, AUSTRIA — The methods of testing iron castings commonly used today have two inherent shortcomings. First, as A. Portevin in his letter to METAL PROGRESS, February, 1932, says, "The resistance of the casting is the only useful data for the user and his engineer, whereas the foundryman alone is interested in the resistance of test pieces separately cast." The second fault of today's test methods lies in the fact that test pieces separately cast do not represent the true properties of the casting itself when the latter has varying cross-sections or wall thicknesses.

A testing method whereby these deficiencies could be avoided would supply the producer as well as the user with valuable data. If for this reason only, it should be generally approved.

The feasibility of such a testing method has been investigated by the writer in the metallurgical laboratories of the Austrian State University. It would appear that most of the difficulties may be overcome by making use of one or two somewhat shorter test pieces, cast in the mold at the same time the casting is poured.

In the past it has been impossible to cast the test pieces as integral parts of the casting itself, because the specified length of the test pieces ($l = 20\ d$) is comparatively great. We have investigated the relationship between length, diameter, and modulus of rupture (and published the results in part in *Giesserei* for August, 1930, and July, 1931), and have proven that shorter test pieces, namely, a length of 10 diameters, can be used without changing the results. Although the bending strength of these shorter test pieces was on the average somewhat higher than that given by bars twice as long, this is of no importance if the shorter ones are used systematically. A test piece five diameters long causes *(Continued on page 66)*

Electrographic Analysis

PRIBRAM, CZECHOSLOVAKIA — In his letter published in the March issue, M. Portevin mentioned a method of non-destructive analysis originated by the present writer. American readers may be interested to know that the test was described in *Zeitschrift für physikalische Chemie* in 1932.

To identify nickel in steel or cast iron, for instance, a small area is cleaned and smoothed, covered with filter paper soaked in dilute alcoholic solution of di-methyl-glyoxime with acetic acid, and pressed down by an aluminum plate. The unknown sample and aluminum plate are connected to one or two 3-volt dry batteries in series as anode and cathode.

When the current flows through the system, metallic ions from the anode pass into the electrolyte, that is, into the paper soaked in a special solution reacting with metal ions, and a corresponding colored reaction is the result — in this case a rose color is produced. Acetic acid is added to eliminate the action of bivalent iron, which also gives a rose coloring with the indicator.

After having systematized the various details of the method, and produced some color standards, the process can be used for rapid and accurate quantitative determinations. Individual determinations may be made in 15 sec., and the analyst can quickly identify suspected bars or segregate scrap.

While other elements in steel may be determined qualitatively, their quantitative estimation is more difficult, since they are usually distributed between solid solution in iron and in carbides. In electrographic analysis all the metals in a solid solution go into the electrolyte simultaneously, and the problem is to devise a "specific" reagent, that is, one that will react to but one metal.

So far, specific reagents are known for both chromium and tungsten. To reveal chromium in steels a dilute solution of benzidine in acetic acid, or di-phenyl-carbozide may be recommended. The presence of tungsten may be detected with a solution of sulphocyanide of potassium and tin chloride.

One interesting application is the determination of the nature *(Continued on page 6[illegible])*

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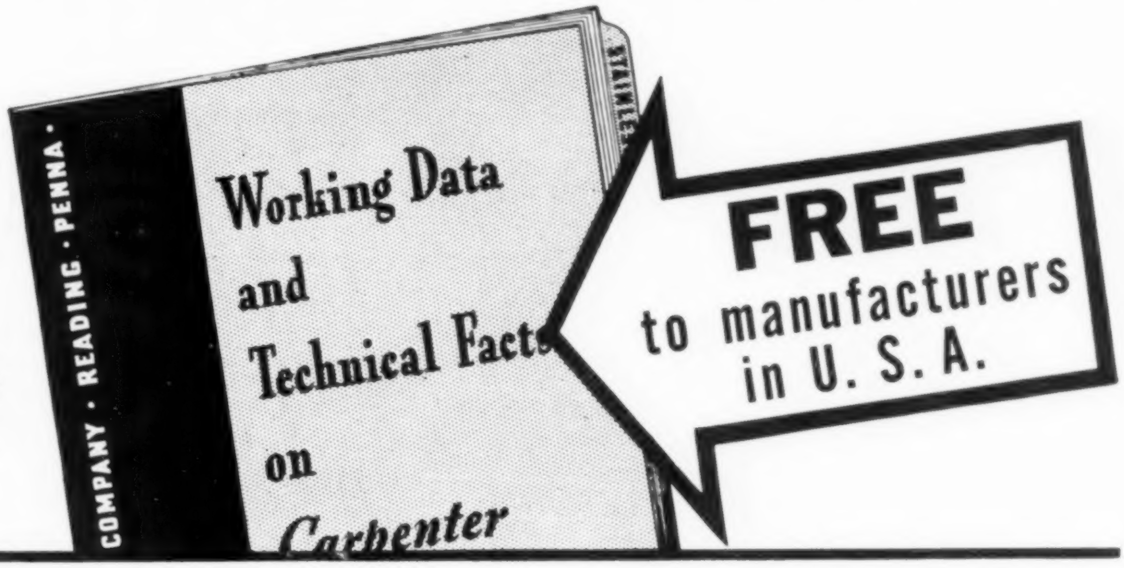

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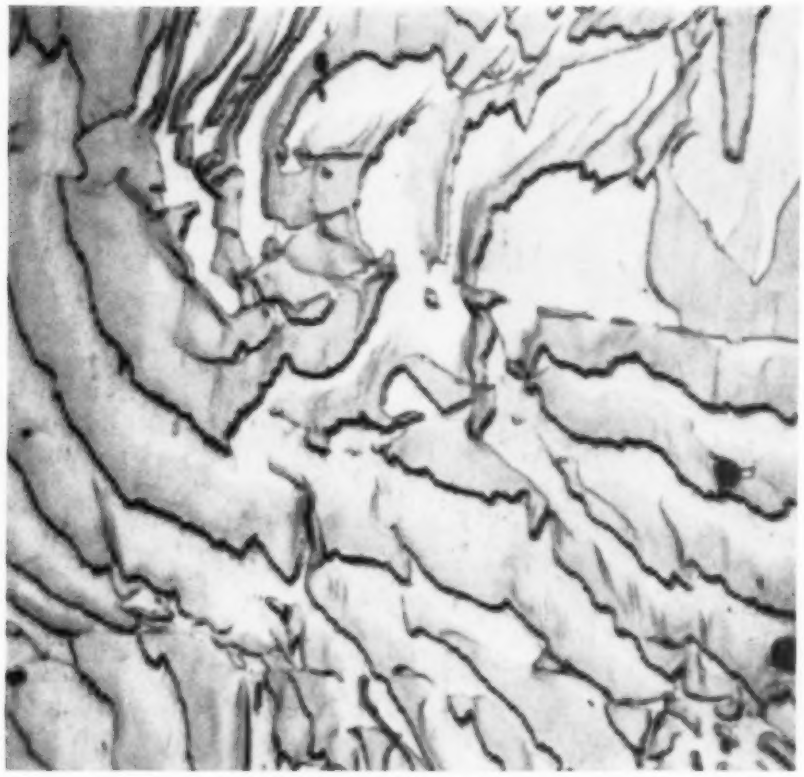

Pearlite showing the lamination in the usual manner and also sectioned at an acute angle. Magnification 3000 ×, 1.7 Ultra-Violet objective, Ampliplan Eyepiece, Vertical U. V. Illuminator.

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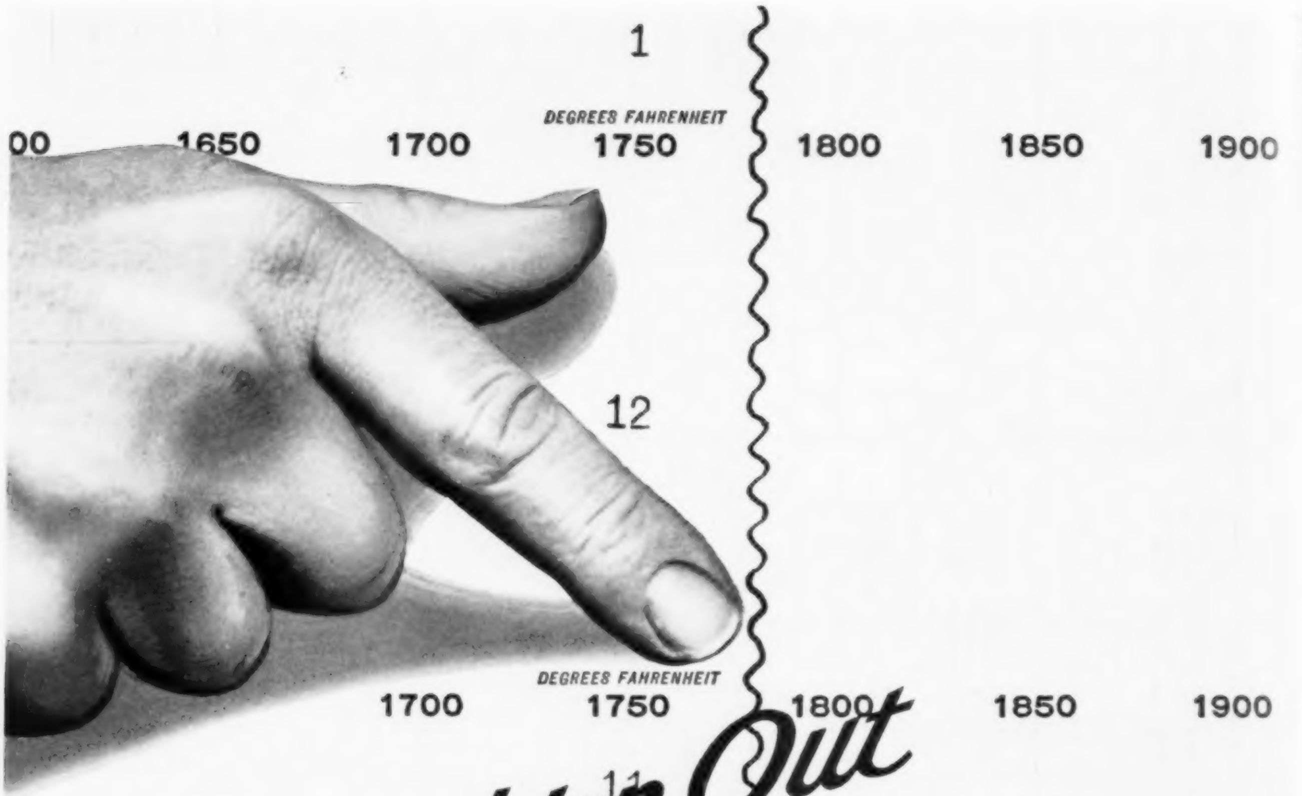

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"Zig-zagging temperatures" mean waste—steady, "straight-line" TRENDALIZER control means better steel, fewer rejects and fuel savings.

The BROWN

correspondence

(Continued from p. 58) of electroplates on metal articles. Less than half a minute is required, using papers soaked with the following four reagents, in the order given:

- Di-methyl-glyoxime for nickel.
- Potassium ferricyanide for zinc.
- Sodium sulphide for cadmium.
- Di-phenyl-carbozide for chromium.

Definite indications may be had with such thin metallic layers as are invisible in a microscopic section examined at high magnifications.

Brasses and bronzes are relatively easy to analyze in this manner, since copper, lead, zinc, and tin are not as similar, chemically, as are the metallic alloys in steel and iron, and hence specific reagents are easier to find.

The electrographic method of analysis is still in its development stages. But as soon as a sufficient amount of experimental data is accumulated as to "specific" reagents and the phasic constitution of complex alloys, this method will allow one to determine quantitatively, within one or two minutes, the composition of the most complex alloys, without destroying or spoiling the test sample.

A. Glazunov
Professor of Theoretical Metallurgy


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correspondence

(Cont. from page 58) too many discrepancies to make its use advisable, but in special cases test pieces eight times as long as their diameter may be warranted.

The second difficulty, which lies in the diversity of the cross-section of the casting, may be avoided as follows: Instead of relying on one test piece, cast together with the casting in the same mold, two of them with various cross-sections should be made simultaneously. Their cross-sections should be selected in such a way that the smaller test piece has the same cooling rate as the thinnest cross-section of the casting, while the larger one should have the same cooling rate as the heaviest wall in the casting itself.

From the physical properties of those two test pieces a conclusion may be drawn at once as to the lability of the material in question and as to its absolute value. (By "lability" we mean the influence of the crystal structure upon the physical properties of the casting itself as they vary with the cross-section.)

Cavities for the test pieces must be placed in the molds so that the iron that is to fill them is at about the same temperature as the average in the casting itself. In other words, one should not place the test piece so that it will be made of iron that has first run through the cold mold of the whole casting.

Test pieces should be fed from the same gates as the casting itself, but not necessarily attached to the latter. Of course, it is frequently possible to attach them to the casting without causing undue additional cost, either in molding or in removing them before testing.

By this method it is therefore possible not only to cast two test pieces of length 8 or 10 diameters simultaneously with the casting itself, but also to determine at once the physical properties of the latter, even if it has various cross-sections. This fulfills demands which may rightly be asked of any test method — it is simple in its use and of equal value to the manufacturer and to the consumer.

ROLAND MITSCHE

pure iron

From what has been said so far, it is clear that we cannot claim that we know much about pure iron. However, using the experimental data in our possession, we may do some speculation.

It is well known that certain elements, such as silicon, aluminum and vanadium, if added to so-called pure iron, improve its magnetic quality, that is, reduce the hysteresis loss and increase the maximum permeability. On the other hand, the same elements increase the A_3 point, and reduce the A_4 point in iron until, with sufficient additions, the two points coincide, causing what is known as a closed gamma loop type of constitutional diagram. We also know that the greater amount of interstitial impurities (such as carbon) present in alloys of this type, the greater the amount of silicon or aluminum that must be added to close the loop.

Graphically these conditions for silicon alloys are represented in an iron-silicon diagram. Would it not be logical, then, to suppose that for zero interstitial impurities it would require zero silicon to close the gamma loop? This is the same as suggesting that the interstitial impurities, up to the present time always present in iron, are responsible for its assuming a face-centered space lattice in a certain range of temperatures, and that the hypothetical chemically pure iron has no gamma state and remains in the body-centered allotropic modification at all temperatures below its solidification point. This condition may be represented in the top diagram, page 29, much magnified in horizontal ordinate.

Since this theory was published, confirmations have come from two independent sources: Hensel in East Pittsburgh, and Esser in Aachen have reported that by applying special purifying processes A_3 and A_4 points in "pure" iron were respectively raised and lowered about 40° C. each. This is in accordance with Yensen's theory.

Whether or not it will ever be possible to produce iron free from allotropy remains to be seen, but we must be prepared for all sorts of surprises, when we finally produce pure iron.

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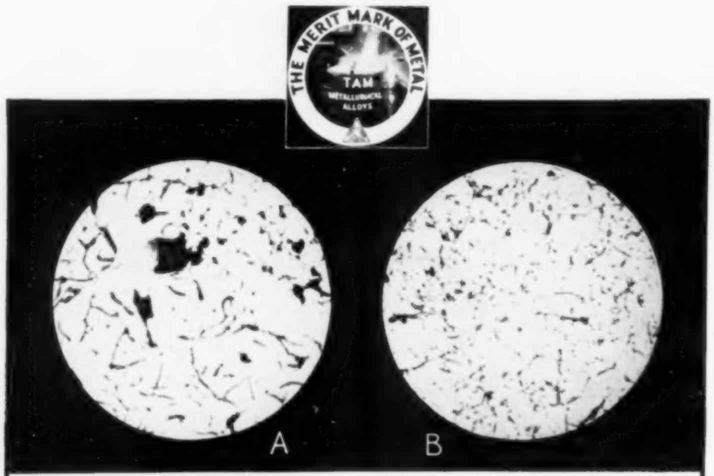

"A" is an untreated cross-section of a gray iron casting. "B" is treated with TAM Standard Low-Carbon Ferro-Titanium. Note fineness of graphite flakes in "B". (Unetched; magnified 50x.)

TAM FCT is used in deep stamping stock for cooking utensils.

TAM Standard Low-Carbon Ferro-Titanium is used in cylinder block mix.

TAM FCT is used in steel forgings for axles, wheels, locomotive tires and rails.

TAM FCT is used in full finish sheets for refrigerators, and strip for auto fenders, etc.

TAM FCT is used in steel for beer kegs, beer ageing tanks, high grade fire box boiler plate.

ALERT foundrymen are finding in TAM Metallurgical Alloys the answers to many difficult problems arising in the production of gray iron castings, high grade forgings, sheet and strip steel as well as stainless steels.

The most striking effect of titanium in castings, and the effect now largely sought in practice, is the refinement of the graphite particles or "closing of the grain." This is well illustrated by the photo-micrographs to the left. The practical result is a high strength, easily machinable iron at low production cost.

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Bristol Co. describes its new pyrometer controller in a bulletin explaining the unique advantages which make possible "degree-splitting" control up to 3000° F., and result in fewer rejects, greater output and longer furnace or oven life. Bulletin Oc-56.

Aerocase Hardening

The Aerocase method of hardening steel in a liquid bath is described in detail in a recent publication of American Cyanamid & Chemical Corp. Full data on the process and its cost, together with a discussion of the metallurgy involved, are presented. Bulletin Oc-28.

Castings to Resist Heat

Ohio Steel Foundry Co. offers an elaborate booklet which covers the production of Fahrite heat resisting alloy castings, illustrating their many uses and giving comprehensive metallurgical data. An interesting section describes their modern plant and equipment. Bulletin Oc-41.

Quicker Heat Treating

Driver-Harris Co. discusses Nichrome sheet containers for heat treating in an illustrated folder which honestly states that while for certain purposes sheet containers cannot be used economically, there are a multitude of installations where their advantages of lightness and quicker heating can be fully utilized. Bulletin Jl-19.

Nitriding Facts

Information on possible new applications of Nitralloy and the nitriding process in view of recent developments may be obtained from Ludlum Steel Co. New economies in product and a better product may now be obtained. Bulletin Jn-94.

Choosing Nickel Steel

International Nickel Co. has an ingenious chart to show at a glance the nickel alloy steel compositions and treatments needed to develop yield points in section sizes from 1 to 12 in. It is useful in selecting bars, shafting and forgings of simple shape. Bulletin Au-45.

Hardness Testing

Everyone interested in the testing of metals for hardness will do well to have on hand a copy of a catalog recently issued by Wilson Mechanical Instrument Co., illustrating and describing the latest design of Rockwell Hardness Testers and auxiliary work supports. Bulletin Sp-22.

High Cr Cast Iron

A pamphlet describing foundry production of cast irons containing from 15 to 30% of chromium has been issued by Electro Metallurgical Co. These cast irons do not grow or scale after repeated heatings and are excellent for high temperature work. Bulletin Ma-16.

Continuous Carburizing

Furnaces for continuous gas carburizing by the Eutectrol process are described in a new folder by Surface Combustion Corp. Photographs of installations and performance data are used to show the advantages of the process. Bulletin Oc-51.

New Zinc Coating

Wire which has been zinc coated by the new Bethanizing process is described in Bethlehem Steel Co.'s latest folder. This process produces a zinc coating which has proved to be more ductile, tighter, tougher, more uniform and purer. Coatings 3 times as heavy as formerly can be made. Bulletin Au-76.

New Type Furnace

A new bell-type retort furnace made by American Gas Furnace Co. can be used in quick succession for carburizing, nitriding, bright annealing in gas atmospheres, or for hardening, normalizing, tempering or annealing. It is an ideal heat treating tool where production is widely varied in character. Bulletin Jn-11.

To Prevent Rust

The well known rust preventive, No-Ox-Id, is now available from Dearborn Chemical Co. as a foundation for paint. It is available in the colors red, gray or black. A booklet explains how maximum resistance to corrosion can be obtained. Bulletin Ju-36.

Pickling Inhibitors

A pamphlet describing the nature and use of Grasselli Inhibitors is available to all those interested in the pickling of steel. It not only describes the merits of these inhibitors, but it gives a table of suggested inhibitor strengths to be used in the pickling of the various grades of steel. Bulletin Ap-95.

2 Everdur Booklets

Two recent publications of American Brass Co. discuss Everdur, the high strength, corrosion resisting copper alloy. One covers its physical properties and resistance to corrosion, the other tells how to weld it. Either or both will be sent. Bulletins Jl-89a and Jl-89b.

Cast Vanadium Steel

Jerome Strauss and George L. Norris have written a technical booklet for Vanadium Corp. of America describing the properties developed by steel castings containing various percentages of vanadium. The information given is complete and authoritative. Bulletin S-27.

Big-End-Up

Gathmann Engineering Co. briefly explains the advantages of steel cast in big-end-up ingots, showing the freedom from pipe, excessive segregation and axial porosity. An 82% ingot-to-bloom yield of sound steel is the usual practice. Bulletin Fe-13.

Low Cost Recorder

Inexpensive dependability in measuring and recording temperature is the great asset of the new Leeds & Northrup round chart Micromax indicating recorder which brings the reliability and easy maintenance of the motor-driven null recorder to a new low cost. Bulletin Ap-46.

Globar Elements

Globar electrical heating units and a variety of accessories for their operation have been catalogued by Globar Corp. A list of the standard industrial type heating elements and a coordinated list of terminal mountings and accessories is included. Bulletin N-25.

"Vee-less" Arc Welds

New literature covering a very recent development in arc welding has been prepared by Metal & Thermit Corp. Known as Murex Straight Gap welding, the new process eliminates grooving or "veeing" the edges even of heavy plates. Welding time is halved and other savings are effected, it is claimed. Bulletin My-64.

Sheffield Steel

Wm. Jessop & Sons, Inc., in a recent publication explain why their Sheffield Superior oil hardening steel does not distort and is easily machined. They assign as reasons a special anneal and a proper balancing of the carbon, manganese and tungsten contents. Full details are presented in Bulletin Jn-61.

Scleroscopes

The model D standard recording scleroscope is described and illustrated in a recent publication of Shore Instrument Co. The theory and practice of hardness testing with this portable machine as described in this bulletin reveal a fund of valuable facts. Bulletin S-33.

Cyanide Baths

Much practical information on the heat treatment of steels with cyanides and salts is contained in a descriptive booklet of E. I. duPont de Nemours & Co., R. & H. Chemicals Dept. The booklet contains many valuable suggestions for improved quality heat treating. Bulletin Sp-29.

Belt Conveyor Furnaces

Full descriptions and photographs of furnaces for economically heat treating small and medium sized parts are given in an 8-page bulletin covering continuous chain belt conveyor furnaces made by Electric Furnace Co. Over 50 such furnaces are now in operation. Bulletin Sp-30.

Titanium Cast Iron

The effects of titanium on the structure and properties of gray cast iron, especially as contrasted with those of other commonly used alloys, are described in a pamphlet offered by Titanium Alloy Mfg. Co. The results given were obtained by regular operating practice in several foundries and not solely by laboratory experiments. Bulletin Jl-90.

New Heat Controller

"Straight Line Control" of furnace temperature is possible with the Trendalizer Controller made by Brown Instrument Co. There is no zig-zagging across the control point, because this unique device changes its control action in accordance with both temperature trend and extent of deviation. Bulletin Sp-3.

Roll Grinding

Carborundum Co. has just published a 50-page booklet on roll grinding which may be considered a handbook of available information on this subject. Carefully written and amply illustrated, this treatise will undoubtedly be of real practical value. Bulletin Au-57.

New Foxboro Pyrometer

Foxboro Co. describes the new Foxboro potentiometer recording pyrometer in a recent bulletin. The outstanding features are a new design of balancing mechanism, ability to make from one to six records, a 12-in. chart, rapid recording cycle and a moisture-proof case. Bulletin Au-21.

Aluminum vs. Corrosion

In the carefully prepared booklet, "Combating Chemical Corrosion with Alcoa Aluminum," published by Aluminum Co. of America, effects of various corrosive agents upon aluminum and its alloys are described in detail. It is an excellent and convenient source of information on this subject. Bulletin Sp-54.

New Furnace Blowers

Two new types of Turbo-Compressors are described in recent publications of Spencer Turbine Co. Uses for the ⅓ hp. Turbo are presented, as is a description of the new single stage Turbo-Compressor which affords tremendous economies in low pressure gas and oil fired equipment. Bulletin Sp-70.

Stainless Sheets

A very useful booklet describing the stainless steel sheets and light plates made by American Sheet & Tin Plate Co. gives recommendations for fabrication and a description of finishes and analyses available. Bulletin Ap-96.

Heat Resisting Alloys

Authoritative information on alloy castings, especially the chromium-nickel and straight chromium alloys manufactured by General Alloys Co. to resist corrosion and high temperatures, is contained in one of that company's publications. Bulletin D-17.

Welding Stainless

An unusual amount of practical data is contained in a fine booklet just put out by Republic Steel Corp. which gives recommendations for welding the several Enduro stainless alloys. Generously illustrated. Bulletin Jn-8.

X-Rays in Industry

General Electric X-Ray Corp. has available a profusely illustrated brochure entitled "Industrial Application of the X-Ray," which gives the complete story of the field of application of this modern inspection tool. Valuable information is presented. Bulletin Ma-6.

Electric Pot Furnace

American Electric Furnace Co. has just published a new 4-page folder showing the construction features and giving the operating advantages of their "American" electric pot furnace as used for lead, salt and cyanide baths. Bulletin Oc-2.

Quenching Handbook

E. F. Houghton & Co. have published an excellent 80-page handbook on the subject of quenching. More than 30 charts and photomicrographs help tell the story. A copy will be sent free to those who request it. Bulletin Jl-38.

Art of Metallography

Bausch & Lomb Optical Co. offers a 130-page book, "Optical Instruments for Examining Metals," which is a beautifully executed source of information on this subject. The book is at once a convenient reference text on optics, a treatise on photomicrography and a catalog of B. & L. products. Bulletin Jn-35.

Uses of Molybdenum

Climax Molybdenum Co. offers a new and useful 50-page booklet dealing with the benefits conferred by molybdenum as an alloying element in iron and steel. In orderly fashion engineering data are presented and made clear with numerous tables and illustrations. Bulletin Au-4.

Maintenance Welding

This interesting booklet describes the use of the oxyacetylene process in the reclamation of broken and worn machine parts, alteration, fabrication and installation of equipment. Such equipment as piping, tanks, machine elements, engine and pump parts and conveying systems is covered in the 16-page illustrated booklet of Linde Air Products Co. Bulletin Jl-63.

X-Rayed Alloy Castings

A folder just issued by Electro Alloys Co. describes their X-Ray inspection service of Thermalloy heat resisting castings for high temperature work. Considerable data on the use of X-Ray tubes and "radon" capsules to check foundry practice are presented. Typical radiographs and tables of physical properties are included. Bulletin Oc-32.

Micro-Metallograph

Metallurgists will be interested in the description of the Leitz Model MM-2 Micro-Metallograph. This simplified instrument at low cost provides all essential optical and mechanical equipment to meet the requirements of industry. Bulletin Fe-47.

Electric Furnaces

Full details of the line of electric furnaces made by Hoskins Mfg. Co. are well presented in their latest 42-page catalog. Contents include description and data on 17 types of furnaces and some valuable information on Chromel resistance wires and thermocouples. Bulletin Sp-24.

Metal Progress
7016 Euclid Ave., Cleveland.

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